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Science for Tomorrow's World

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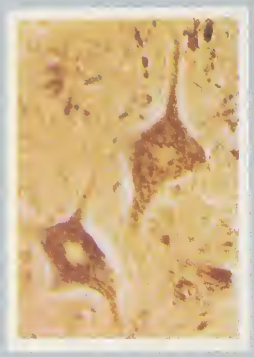

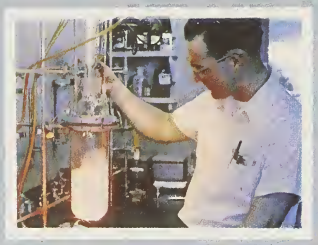

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Science for Tomorrow's World 5

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THE MACMILLAN COMPANY, NEW YORK
COLLIER-MACMILLAN LIMITED, LONDON

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EDITORIAL ACKNOWLEDGMENTS

CHARLES KNUDSEN, Manager, Operations, U. S. Weather Bureau, Region 1, for permission to photograph members of the New York City Weather Bureau in the performance of their duties and for verifying the accuracy of the picture story *A Visit to the Weather Bureau.*

ANDREW L. WESSLING, Jr., Woods Hole Oceanographic Institution, for permission to use the Institution's photographs in developing the picture story *Probing the Oceans* and for verifying its accuracy.

A Visit to the Weather Bureau and *Probing the Oceans* picture stories were conceived and developed by SIDNEY SELTZER. The weather story was photographed by MARTIN SAUBER of Diversified Photo Services.

COVER ILLUSTRATION BY
Pan Visual, Cambridge, Mass.

COVER PHOTOGRAPH BY
Lew Merrim—Monkmeyer Press Photo Service

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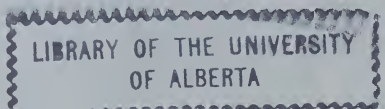
The Macmillan Company, New York
Collier-Macmillan Canada Ltd., Toronto, Ontario

PRINTED IN THE UNITED STATES OF AMERICA



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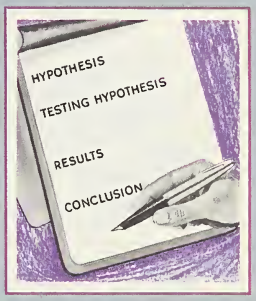

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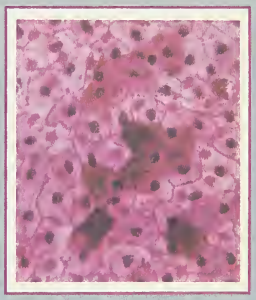

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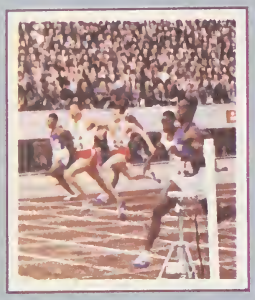

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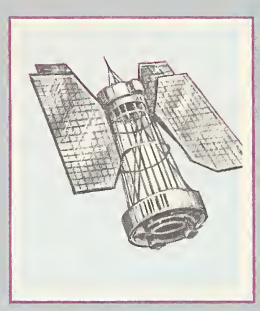

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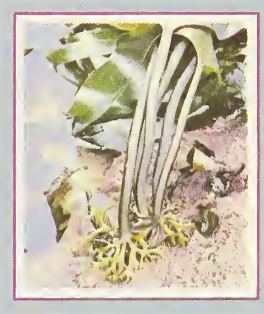

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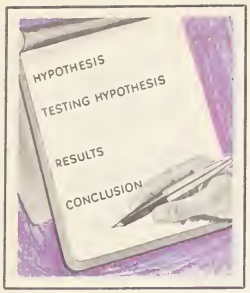
The Scientist's Way

1

Testing Ideas

Ways to Get Answers
How Sure Can You Be?



How can the weather be changed or controlled? What causes undersea waves? How can a cold-preventing vaccine be made? Science is a search for answers. Scientists are the searchers. The ideas they get in their search must always be tested. When you test your ideas, you are working like a scientist.

Ways to Get Answers

You have a question that you want answered or a problem that needs to be solved. How do you go about getting an answer? Suppose you wanted to test the idea that air can push things. You might put a piece of cardboard on top of a glass of water. Then you might turn the glass upside down. You might decide, based on what you already know, that the water will stay in the glass because the air pushes up against the cardboard and holds it there. One fifth-grade class tried the experiment, but it did not work. The water poured out of the glass. Luckily the class performed the experiment over a basin.

Their teacher asked them why the experiment did not work. Here are some of the ideas that the boys and girls had:

1. The water spilled because the glass was not turned over quickly enough.
2. The cardboard should have been thicker.
3. The boy who held the glass jiggled his hand.
4. Water is heavier than air, and it pushed the cardboard from the glass.
5. There was a little air on top of the water in the glass, and it pushed the water out.

These are some of the ways to get ideas about the world around you. Can you identify each way? Which of these ways do you use to find out about things?

Where did the boys and girls get their ideas? They got their ideas from observing, from reading, from earlier experiences, and from thinking about the problem. Scientists get their ideas and answers in the same ways.

Forming a Hypothesis

Do you think that a scientist spends all his time peering through a telescope or a microscope in a laboratory filled with gleaming equipment? A scientist often develops his ideas about problems even when he is very far away from his work in a laboratory. A trained mind and a natural curiosity about the world are a scientist's best tools.

When a scientist has a problem to solve, he puts the problem in the form of a question. Then he, alone or with other people interested in the problem, tries to arrive at an answer by observing, reading, or thinking. When a possible answer comes to mind, this is called a **hypothesis** (hy-POTH-uh-siss). The plural of *hypothesis* is *hypotheses.*

Forming a hypothesis is not the same as solving a problem. A hypothesis is simply a guess about the answer to a problem. It is the first step in finding the answer. Next, the hypothesis must be tested to see if it really is the correct answer, if it really does solve the problem.

Everyday Hypotheses

You form hypotheses every day about things that puzzle you, though you may not call them hypotheses. You often try to explain things to yourself. You may have a question about something you hear or read. You form a hypothesis to answer this question. But have you ever tried to figure out how your hypothesis could be tested?

Jerry had some goldfish in a tank in his room. These goldfish were about two inches long. His friend Mike looked at the fish and said, "Oh, they're nothing! You should see my goldfish. They grew

Scientists form hypotheses about things that puzzle them. What hypotheses can you form about the things you see the scientists doing?

to nine inches because they were kept in a pool outdoors all summer."

Jerry did not believe his friend. He asked this question: Can goldfish grow to be nine inches long? He formed this hypothesis: No, goldfish do not grow any bigger in an outdoor pool than in an indoor tank. Therefore, Mike's fish are not goldfish. How do you think Jerry's hypothesis could be tested?

Here are some other problems:

1. How do dogs know when a cat is nearby? Billy says that all dogs are nearsighted and usually do not see cats. They smell them. How could you find out if Billy is right?

2. The kindergarten class has asked the fifth grade to help in wiring the kindergarten doll house for electric lights. Some of the pupils say they can make brighter lights by using more than one dry cell. How can their hypothesis be tested?

3. A fifth-grade boy is trying to decide what kind of suit is best for astronauts who go to the moon. He thinks an asbestos suit would be best. How can his hypothesis be tested?

Which of these hypotheses could you test yourself? Which ones sound like wild guesses?

To form good hypotheses, you have to know something about the problem. To form a good hypothesis about astronauts' moon suits, you need to know what it is like on the moon. Is there air on the moon? Is it hot? Is it cold? Is there sound? Is there gravity? Later in this book you will learn something about space and the moon. Then you may be able to make a good hypothesis about moon suits and how they will have to be designed.

Testing a Hypothesis

In modern science a hypothesis must be tested many, many times before it is accepted as fact. Certain rules for testing a hypothesis have been developed. What are some of these rules?

People once believed that heavy things fall faster than light ones. You can do an experiment to test this hypothesis. Before you experiment, you must make a plan.

First you must decide what you are going to drop. You must decide on the shapes and weights of the things you will drop. Then you must decide how many objects you will drop. You may decide to drop two things.

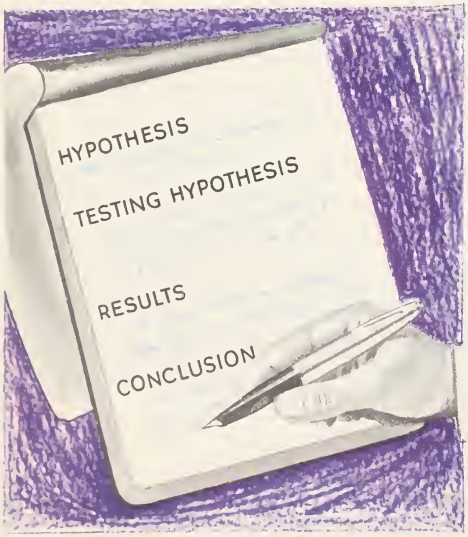
How far will you drop the things? Why should both things be dropped from the same height? How will you

make sure that they are dropped from the same height?

Should both things be dropped at the same time? Can you tell when they hit the ground just by watching them? Would it be better to listen for the sound they make when they hit the floor?

Finally, you must decide how many tests you should make. Is one test with two things enough? If not, how many tests with how many things are needed?

When you have decided what plan you will follow, write it out. The report of your experiment should include: (1) what your question was and a statement of your hypothesis; (2) a description of the plan you used to test the hypothesis; (3) what you found out; (4) your conclusion—whether the experiment seemed to prove or disprove your hypothesis.



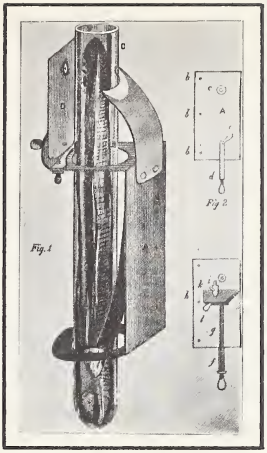
Hypothesis and Theory

Sometimes a scientist forms a hypothesis as a result of his own research. At other times a scientist forms a hypothesis from information that other scientists have gathered. For example, here is an important hypothesis which is accepted today: All living things are made up of cells. This hypothesis is the result of the work of two German scientists, Matthias Schleiden (SHLY-den) and Theodor Schwann (SHVON). They formed the idea from the reports of other scientists.

As you know, a microscope can be used to see very small things. Before it was invented, no one knew that there were tiny plants and animals too small to be seen by the eye alone.

About three hundred years ago, a Dutch scientist named Anton van Leeuwenhoek (LAY-vun-hook) invented a microscope and with it saw tiny animals in water. Another scientist saw tiny, boxlike compartments in certain plants; he called the compartments cells. With the aid of the microscope, more and more was found out about cells. Each scientist reported to other scientists about his discoveries.

In the nineteenth century, Schleiden and Schwann read the reports of these other scientists. As they read, they



This picture shows Anton van Leeuwenhoek and one of the microscopes he made. Can you tell how the microscope worked? How would you go about finding out?

formed the hypothesis that *all* living things are made up of cells. They checked the reports of still other scientists. Of course, they could not examine all the different kinds of plants and animals that were found in the world. But they did make many observations that led them to their idea.

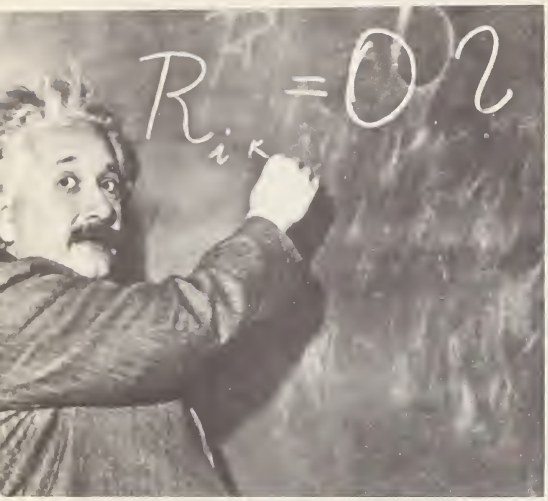
This hypothesis has been tested over and over by other scientists. The results were always the same. A hypothesis such as "All living things are made up of cells" is called a **theory** (THEE-uh-ree). A theory tries to show the connection among many facts. All living things, from the smallest one-celled plant or animal to the largest, are made up of cells. This is the **cell theory** of living things.

Einstein and the Atom

Scientists get their ideas and form their hypotheses by observing, studying, and thinking. Fine laboratories and books help, but a theory really comes from the scientists' minds.

Albert Einstein (YN-styn), one of the greatest scientists who ever lived, formed a very important theory about the universe. The tool with which he worked was not expensive laboratory equipment, but mathematics. A hypothesis about the universe cannot be tested in the same way that a hypothesis about cells can be tested. Can you tell why? Scientists who understand Einstein's mathematics accept his theory.

You have already learned that everything in the universe is made up of



Albert Einstein, a famous scientist, used mathematics to form many scientific hypotheses.

atoms. One of Einstein's mathematical theories has helped man to use energy from atoms. The first important use of this atomic energy was in warfare. Fortunately, atomic energy can now also be used for many peaceful purposes—as a source of energy in factories, in medical treatment, and in other ways that help people have a better life.

Another Way to Get Answers

Forming and testing hypotheses is one way to get answers. But there is another way that you use every day. Perhaps Marion's problem will give you an idea of what the other way is.

Marion tried not to soil her new cotton skirt as she ate a peach. Somehow, a little juice dripped on her skirt. What could she do? She might have thought: (1) I will remove the stain with warm water and soap; (2) I will remove the stain by rubbing it; (3) I will remove the stain with cleaning fluid. Why would it not be wise for Marion to test all these hypotheses?

In this case, there was a better way to find out what to do. Marion decided to get help from a good source, so she used her mother's cookbook. Under *stains,* in the index, she found *peach.* Marion read the directions: "Stretch material with stain over a bowl. Pour boiling water from a height so that it falls on stain with force. Repeat if necessary. The stain will disappear."

Marion used a very important way to get an answer. She went to a source for her answer. She did not go to a friend who might not have the information or experience. She used a reliable source, the cookbook, to help her solve the problem.

Is it always practical to test an idea yourself? Of course not. Sometimes you do not have the necessary information. Sometimes you do not have enough time or equipment. Sometimes it would be too dangerous. You can go to a reliable source for help—a source that you know has the information.

These are some of the many sources you might use to find the answers to questions you have in science. How would you decide which source to use?

How would you find the answer to the question, "Why is it hotter in your city in summer than in winter?" Suppose your hypothesis was that the temperature had something to do with the earth's path around the sun. Would you be able to test that idea easily? You would probably have to turn to a good source to find the answer. What source would you use? An encyclopedia? A newspaper? A science textbook? These may be good sources, but not all sources are good ones. Knowing where to get accurate help is important.

Using What You Have Learned

Discuss the following statements and their sources with your class. Which speaker may be called an expert on the subject on which he is speaking?

a. Dr. Anthony Wilding, professor of mathematics at Tompkins University, announced today the publication of his new book, *Why Jamie Is a Poor Reader.* He stated that if parents carefully study his book and help their children, they can be sure that their children will become good readers.

b. Dr. Heinz Haber, director of the United States School of Space Medicine, stated that one of the major problems in space travel will be to protect the eyes of space travelers.

c. Mrs. Robert Lode, a wealthy lady from Levelton, Arizona, states that Benson's coffee is the best coffee. She says that she always serves it at her dinner parties because "it is the richest, most flavorful coffee."

d. Dr. James Smith, medical director of the Hamilton Hospital, stated today that he will vote for Mr. Anthony Palowski for City Council. He declared, "I feel Mr. Palowski has done a splendid job during his present term and should be re-elected."

How Sure Can You Be?

Jim and Tom wanted to go to the circus. Jim asked his mother if he could go. "Probably," said his mother. Jim was delighted. Tom asked his mother if he could go. "Probably," said his mother, but Tom was sad. Why did the boys have such different reactions? "When my mother says 'probably'," explained Jim, "nine times out of ten I get permission to do what I asked to do." "But when my mother says 'probably'," sighed Tom, "nine times out of ten I don't get permission."

Scientists, too, work with the idea of how probable it is that a thing will happen. But scientists are more exact in the use of the word *probable* than other people are. For example, scientists conducted an experiment feeding white rats. Fifty rats were given a certain amount of milk in their diet. Another fifty rats of the same age, weight, and health were given the same diet as the first group except that they received no milk. The rats that drank milk always gained more weight than those that did not drink milk. The scientists could predict that the amount of the extra weight increase would always be somewhere between 8 and 12 grams.

Understanding Probability Theory

Did you have milk for breakfast this morning? Will you have milk for breakfast tomorrow? You can probably be fairly sure you will because you know you have had milk in the past. But what if you are ill, or you oversleep, or your mother forgets to buy milk? You can say that while the probability you will have milk is great, you cannot be sure.

In fact, scientists say that nothing is absolutely certain to happen or not to happen. The truth of any hypothesis is only probable. How likely a thing is to happen, or its probability of happening, is often very important for a scientist to know.

Try this. Every penny has two sides. One side is called the head. The other side is called the tail. If you toss a penny into the air, there is an equal chance that it will land with its head or its tail facing up. Mathematicians say that the probability of getting a head on any toss is one chance out of two. They represent this chance by the fraction ½. The probability for getting a tail is the same.

Toss a penny ten times. Record heads and tails by making a tally in two columns. How many heads did you get? How many tails? Show the relation of heads to the ten tosses as a fraction. With ten tosses, the probability is low that there will be an equal number of heads and tails. If there is time, each person in the class should toss a penny ten times. Tally the results on a class chart. How many heads did the class get? How many tails? Show the relation of heads to the total number of tosses as a fraction. Compare this fraction with the first one. Do you find that the proportion changes with the increased number of tosses? Do the chances become greater that the number of heads will equal the number of tails?

If you were to toss a penny a thousand times, it is very probable that heads would turn up 500 times and tails would turn up 500 times. In other words, the probability is high that the number of heads would equal the number of tails.

Now test yourself to see how much you really understand about probability. On a piece of paper, write the numbers 1 through 5. Read the following sentences, and write *true* or *false* for each sentence.

1. If I get a head when I toss a penny, the next time I toss I probably will get a tail.

2. If I toss a penny 10,000 times, I probably will get 5,000 heads.

3. If I toss a penny 10,000 times, the probability is that the number of tails will be equal to the number of heads.

4. If I toss a penny 25 times, it is not probable that I will get heads every time.

5. If I toss a penny 25 times, it is impossible for the coin to fall on heads every time.

When you understand the answers to these questions, you are ready for the next step.

Toss two pennies into the air. Here are the possibilities:

two heads,
two tails,
one head and one tail,
one tail and one head.

Notice that there are four possibilities. Are you more likely to get two heads, or a head and a tail? You are more likely to get a combination of a head and a tail. The reason is that there are two chances in four of getting a head and a tail and only one chance in four of getting two heads. How can you write these two possibilities as fractions?

How about two tails? There is one chance in four of your getting two tails. Can you see why it is more probable that you will get a head-and-tail combination than two tails?

Now work out this probability problem. A dog has two puppies. What is the probability that both puppies will be males? What is the probability that there will be one male and one female? Two females?

Figure out the number of possibilities. In this case, there are four possibilities. Then figure out how probable each possibility is. There is one chance in four that both will be males and one chance in four that both will be females. There are two chances in four that there will be one male and one female. Scientists figure out the number of possibilities and the probable occurrence of each possibility in their experiments. This is the basis of **probability theory.**

Scientists use probability theory to make predictions. They figure out how probable it is that a certain vaccine will work. Or they predict how probable it is that a certain material will be able to resist the great amount of heat caused by the friction of the atmosphere when spaceships return to earth. They can also figure out how many people probably will get a disease.

You can now see how important probability theory is. By using probability theory, scientists can put to work their vast scientific knowledge about the world we live in.

Keeping Records

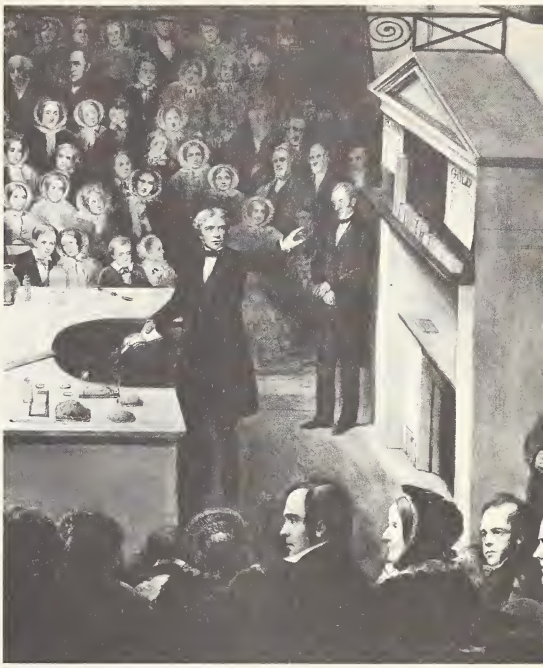
Scientists keep careful records of the ideas they have tested. These records make the results of their work available to other scientists. These records also make predictions possible.

Michael Faraday (FAR-uh-day) was an English scientist who, in the nineteenth century, discovered much about magnets. He wondered whether a coil magnet has magnetic power all the way through or just on the outside. Faraday performed experiments and kept a very careful record of what he observed. You can try his experiment just as he described it in his notebook.

"A [coil] of silked copper wire was made round a glass tube. . . . A magnetic needle nearly as long [as the glass tube] was floated with cork, so as to move about in water with the slightest impulse. The [coil] being connected with the apparatus and put into the water in which the needle lay, its ends appeared to attract and repel the poles of the needle. . . ."

In Faraday's time, there was no insulated wire. He used plain wire, wrapped with silk. Why should you use only insulated wire when you do his experiment?

After repeating Faraday's experiment, tell what happens to the needle.



Michael Faraday, whom you see speaking in the picture, kept very complete records. How has this helped later scientists?

Now bring the coil nearer to the needle. What happens as the coil is moved toward each end of the needle?

Next bring the coil very close to the end of the needle that attracts the coil. What happens? Faraday found an answer to his problem. His experiment showed that a magnet had magnetic force all the way through it.

Faraday's careful records were used by many other scientists. For example, Thomas Edison used them to help him develop the electric light.

The Continuing Scientific Search

A scientist does not stop searching when he finds a good answer. There may be a better answer. For example, when gasoline engines were invented, automobiles were produced. But scientists did not stop investigating with the production of the first gasoline engine or with the first automobile. They sought to find the answers that would enable them to build engines that are easier to start. They also tried to streamline the car, to make comfortable seats, and to make safer, stronger tires.

Airplanes are another good example. The first airplane that the Wright brothers made flew a distance of about 850 feet in 59 seconds. It was made out of wood and cloth. From that simple beginning, scientists have made great strides. Airplanes can now fly at more than twice the speed of sound and more than fifteen miles above the surface of the earth.

Scientists never stop working on important problems. New facts that make the old answers incomplete are always being discovered. New answers have to be found to explain the new facts. Science is never finished with a problem. Science is not a book full of facts, but a way of using facts and testing ideas.

PATHFINDERS IN SCIENCE

Marie Curie

(1867–1934) Poland

Marie was well educated by her father. She became a teacher so that she could save money and send some to her sister in medical school. While Marie taught the children of wealthy parents, she read every book and booklet on science she could find.

By 1891, Marie had saved enough money to go to Paris to study. She lived in attic rooms for three years and ate little more than buttered bread and tea. She had discovered her lifework, science, and cared for nothing else. After her graduation, she met a French scientist named Pierre Curie. Marie went to work in his laboratory. Soon afterward they were married.

Henri Becquerel (bek-REL) had discovered that uranium ore gives off energy. He talked about his discovery with the Curies. Marie decided to do research on uranium. She made many different tests. Repeating her experiments over and over again, checking one kind of test against another, she proved that the strength of the energy given off by a piece of uranium ore was exactly equal to the amount of uranium in the ore. Her conclusion led her to a question: If uranium gives off energy, are there other elements that do the same thing? She

tested thorium. She found that thorium also gives off energy. Knowing these facts, Marie Curie stated that certain elements had what she called *radioactivity*. She invented this word, which is a familiar one today, and started an entirely new area of research in chemical and physical science.

Marie and Pierre Curie dedicated their thoughts and work for the rest of their lives to the study of radioactive elements.

In a leaky shed in a courtyard outside their office, she and her husband examined scores of untested minerals. She found that the mineral pitchblende gives off four times the amount of energy that the same quantity of uranium does. Not one of the known elements in pitchblende was radioactive. Marie came to the conclusion that pitchblende must contain one or more elements unknown to scientists. Aided by her husband, she set out to test her idea. Using every known scientific test, they separated a new element from pitchblende. They called it *polonium,* in honor of Poland.

The Curies believed that there was another unknown element in pitchblende. Again they tested their idea. In eight tons of ore they found a mere speck of the new element, *radium*. It could not even be weighed. A few years later they had one three hundredth of an ounce of pure radium! This amount would have sold for $150,000. The Curies decided to keep it

for further study, because selling it, as Madame Curie said and Pierre agreed, would be "contrary to the scientific spirit."

It was found that radium could cure certain cancers. In 1903, Marie and Pierre Curie won the Nobel Prize for the discovery of radium. In 1911, Marie Curie won a second Nobel Prize, for the extraction of radium. She is the only person to have been honored twice by the highest scientific award.

Madame Curie's daughter Irene also received a Nobel Prize in science, in 1935. However, Madame Curie did not live to see her daughter honored. Madame Curie died of a disease brought on by exposure to radium, the element she discovered for the world.

Using What You Have Learned

1. Repeat the Faraday experiment described on page 13. This time use a floating needle that is shorter than the tube. What happens?

2. Tell if and how each of the following hypotheses could be tested. Choose two hypotheses from the list that you can test yourself. Plan experiments to test them. Carry out your experiments carefully.

a. At night, light clothing can be seen more easily than dark clothing.

b. Dresser drawers stick in the summer because heat makes things expand.

c. People can learn to spell better by studying ten minutes a day six days a week than by studying an hour one day a week.

d. Eating carrots will make straight hair curly.

e. When the sky is red in the evening, the next day will be fair.

f. Air conditioners work better when the windows are closed.

g. If you use a special wool soap to wash woolens, they will not shrink.*

h. If you drink milk, your nails will be stronger.

i. Fifth graders write more legibly on ruled paper than on unruled paper.

j. Dark clothes make people appear slim.

k. Homemade cake will stay fresh longer than cake made from a packaged mix.

l. Plastic heels wear longer than leather or rubber heels.

m. You can see better in yellow-colored light than in red-colored light.

n. Sound travels in water as well as in air.

*Temperature of the water is a significant variable in this experiment.

3. As you have learned, it is not sensible, or even possible, for boys and girls to try to find the answers to all questions by testing. But knowing where to find answers is very important. Here are some questions that boys and girls have asked. How would you go about finding the answers?

a. Is New York City bigger than London, England?

b. How many games did the New York Yankees win in 1965?

c. Does white bread have more vitamins in it than whole-wheat bread?

d. Who invented radar?

e. How much did the first man-made satellite weigh?

f. Is any part of the west coast of South America farther east than part of the east coast of North America?

4. A penny must have all of its edge sharp if you are to have an even chance of getting a head or a tail when you toss. Why is this so? Try to find a penny that is not perfect in this respect. Toss it many times to see if an imperfect penny changes the chances.

5. Toss three coins at one time. What are all the possible results that you might get? What is the probability of getting each one? Can you express the probabilities as fractions?

6. When people travel in airplanes, they often buy air insurance. How does the probability theory affect the rates of air insurance?

7. Use the table to show how probability theory affects life insurance rates.

Age	Annual Premium for $10,000
30-34	$38.60
35-39	$52.70
40-44	$72.30

WHAT YOU KNOW ABOUT

The Scientist's Way

What You Have Learned

Scientists have many questions about the world in which we live. They see many problems that need to be solved. Scientists have certain ways to go about solving problems and finding answers to their questions.

When a scientist has a problem to solve, he thinks of possible solutions. He puts the problem in the form of a question. Then he tries to figure out the answer by observing, reading, or thinking. He tries to make a good guess about the answer to the problem. Such a guess is called a **hypothesis.** The scientist may also form his hypothesis by putting together the information that other scientists have gathered. After he forms his hypothesis, the scientist tests it many times to see whether it is correct. When a hypothesis is found to be correct by many scientists, it is called a **theory.**

Scientists say that things are not absolutely certain to happen or not to happen. How likely a thing is to happen, or the **probability** of the thing's happening, is often very important for a scientist to know. The **theory of probability** enables scientists to figure out the number of possibilities and the probable occurrence of each in their experiments. Using probability theory, scientists can plan ahead.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

hypothesis theory theory of probability

How Scientists Test Ideas

How did the scientists listed below test their ideas?

Jan Ingen-Housz
James Joule
Galileo
Robert Boyle

Complete the Sentence

Write the numbers 1 to 3 in your notebook. Next to each number, write the word or words that best fit the space in each sentence.

1. A good guess about the answer to a problem is called a ___?___.
2. A ___?___ is an attempt to explain the facts that have been discovered.
3. Scientists use ___?___ ___?___ to figure out the number of possibilities and the probable occurrence of each in their experiments.

Where Would You Look?

List the numbers 1 to 6 in your notebook. Next to each one write the source you would use to find the answers to these questions.

newspaper encyclopedia science textbook

1. How fast does sound travel in water?
2. What will the weather be today?
3. Does air pressure become lower as one goes higher in the atmosphere?
4. Who was the pioneer of American rockets?
5. How does an electron microscope work?
6. Were any rockets launched last month?

YOU CAN LEARN MORE ABOUT

The Scientist's Way

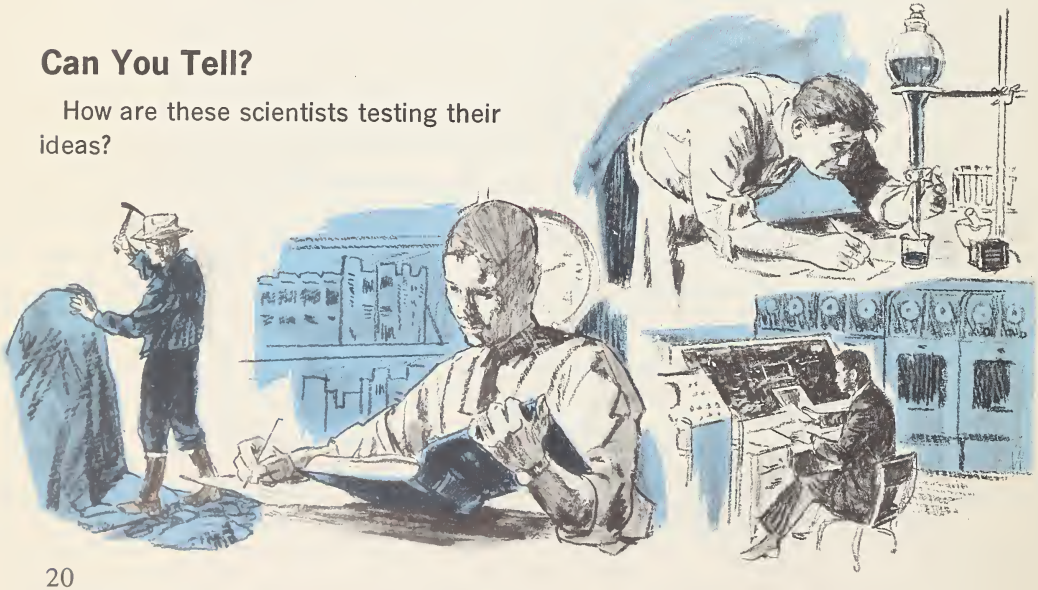
Testing Hypotheses

Make up a hypothesis to answer each of the questions below and then tell how you would test your hypotheses.

1. What organisms live in the soil?
2. How can snowflakes be photographed?
3. Is warm air pushed up by cold air?
4. Do younger and newer layers of rock rest on lower and older rocks?

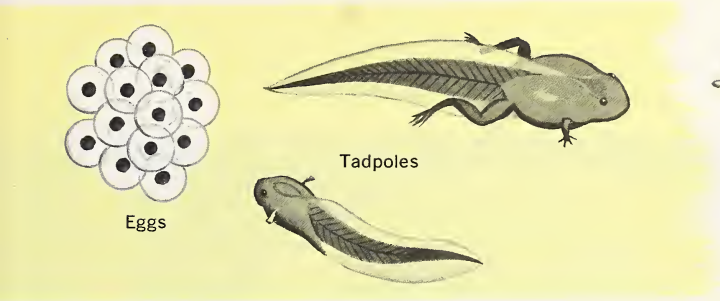
Can You Tell?

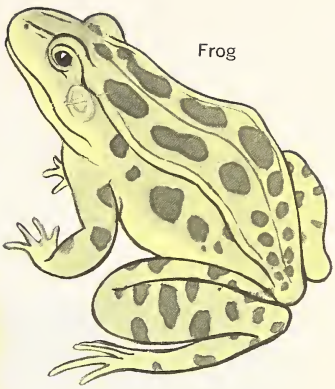
How are these scientists testing their ideas?



What Do You Think?

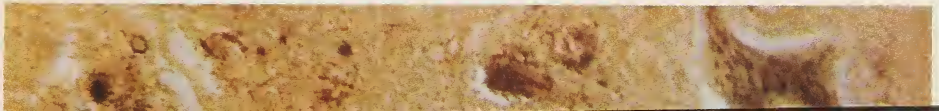
Look at the three pictures below. What do they have to do with the frog on the right? How can you test your ideas to see if you are right?

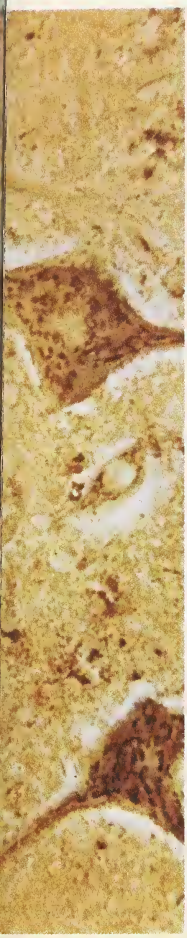




You Can Read

1. *It's Fun to Know Why,* by Julius Schwartz. Simple experiments help you uncover the secrets contained in coal, glass, soap, wool, and other materials.
2. *Here's How It Works,* by Duane Bradley and Eugene Lord. You will learn how many machines, tools, and scientific devices work.
3. *The Crazy Cantilever, and Other Science Experiments,* by Robert R. Kadesch. You can do over 40 experiments in physics by following the simple directions in this book.
4. *Science Puzzlers,* by Martin Gardner. A more advanced book than the others, but with it you will have much fun and learn much about science.

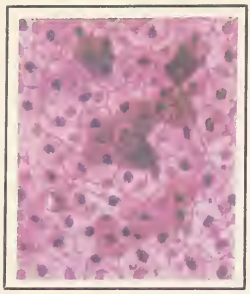




2

Cells, Tissues, Organisms

Discovering the Cell
Examining the Cell
From One Cell to Many Cells



Discoveries in science are made because scientists build on the work done by other scientists. The ideas of one man may start other men thinking. One discovery may lead to many others. In this unit you will learn about some exciting discoveries that were made following the invention of the microscope.

Discovering the Cell

Why do you grow? Why do you stop growing? Why is each of you different from every other living person? How do life and growth begin? Man has always been curious about life. Scientists now know that all living things are made up of **cells.** To study life, you must study the cell.

A very simple animal such as the ameba is made up of only one cell. Within this one cell, all the life activities are carried on—getting food, using food, getting rid of wastes, and producing more cells like itself.

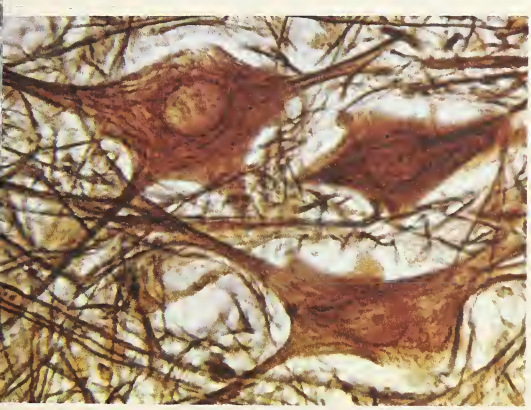
Most animals, unlike the ameba, are made up of many cells of different

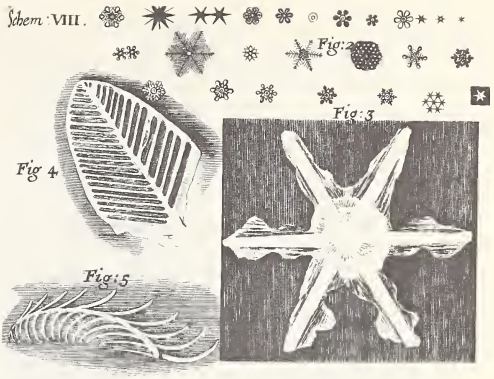
This is a model of a cell. It shows how a cell might look if it were magnified many hundreds of times. You can see that there are many parts within the cell.

kinds. Each different kind of cell carries on a specialized job. You are a many-celled animal. Right now, the cells in your brain are carrying on the special job of storing away information about what you are reading.

Cells are very small. They must be magnified many times under the lenses of a microscope to be seen and studied. Until four hundred years ago, scientists did not have the instruments to study cells or any other very small objects. The invention of the microscope in the 1600's made it possible to see very small things. Invisible worlds that men did not even know existed became visible under the lenses of the microscope. It was now possible to explore these worlds.

These cells are found in the human brain. What special job do you think such cells have?



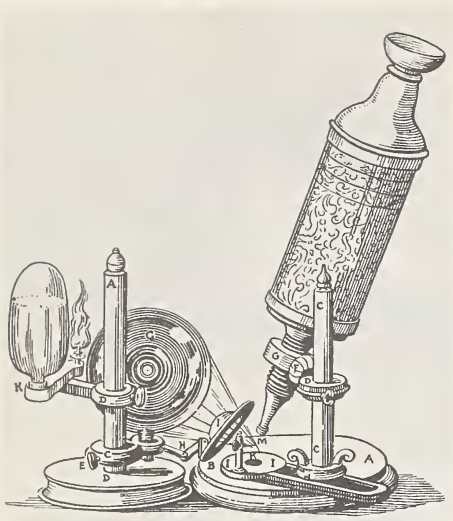


Robert Hooke observed many objects with his microscope and made drawings of what he saw. What do his drawings above show?

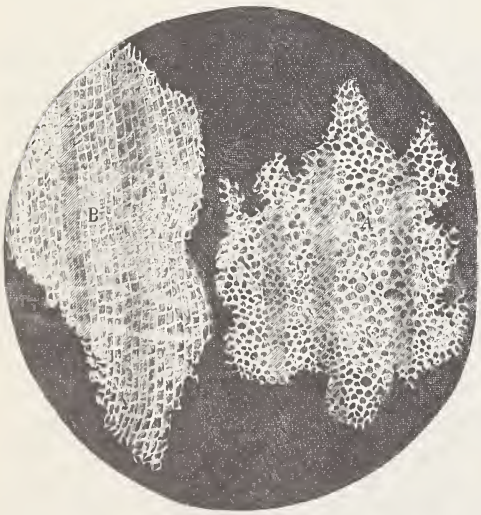
Robert Hooke Looks at Cork Cells

In the 1660's the curator of experiments of the Royal Society of London was Robert Hooke. Hooke improved the microscope so he could explore the unknown world of very small things. Keeping careful notes and making detailed drawings, he studied many things under his microscope. Among these things were a bee, a flea, and a thin slice of cork. The most important of his observations were made about the slice of cork. Here are some of Hooke's comments in his own words about what he saw.

"I took a good clear piece of cork and with a pen-knife sharpened as keen as a razor, I cut a piece of it off, and thereby left the surface of it exceedingly



Robert Hooke used the microscope shown above to look at a thin slice of cork. The drawing he made is shown below. What do you see?



smooth, then examining it very diligently with a microscope, me thought I could perceive it to appear a little porous. . . . I with the same sharp pen-knife, cut off . . . an exceeding thin piece of it." (He then placed it under his microscope.) "I could exceedingly plainly perceive it to be all perforated and porous, much like a Honey-comb, but that the pores of it were not regular. . . . These pores or cells were not very deep, but consisted of a great many little boxes. . . . Nor is this kind of texture peculiar to cork only: for upon examination with my microscope I have found that the pith of an Elder or almost any other tree, the inner pulp of several . . . vegetables . . . have much such a kind of Schematisme as I have lately shown that of cork."

In his description, Hooke described the holes in the cork as "cells." He used the word *cells* because the holes made him think of the cells of a honeycomb. This was the first time *cell* was used in print to mean a part of a plant.

The Cell Theory

Later, other scientists studied living things with a microscope. They saw what Hooke had seen and more. In 1824, Henri Dutrochet (doo-troh-SHAY), a French surgeon who retired in order to have more time to study and

Theodor Schwann and Matthias Schleiden developed the cell theory over one hundred years ago. How did this theory advance man's understanding of living things?

experiment, stated that all living things are made of cells. After many observations, he said also that growth results from an increase in the size of existing cells and from the addition of new, smaller cells which increase in size.

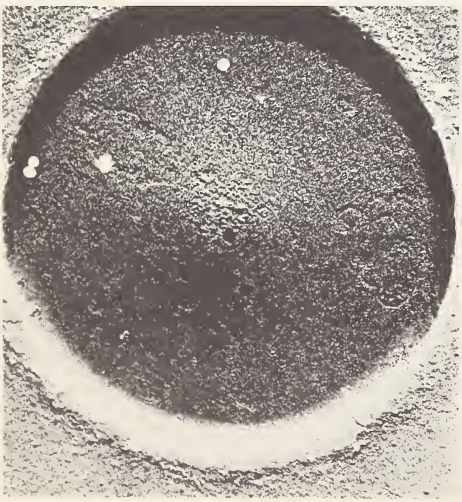
Before other scientists would accept Dutrochet's findings, they needed more detailed and complete evidence. It came fifteen years later when, in 1838 and 1839, Schleiden and Schwann published their findings. Schleiden discovered that plants are built of cells and grow from single cells. Schwann found the same to be true of animals. He was the first to use the phrase *cell theory*.

The cell theory says that all living things are made of one or more cells or of cells and their products. As a result of the work of many scientists, the cell theory now includes more information: All cells come from cells, and the activities of all living things are possible because of the activities in cells.

Scientists today have a much more powerful instrument with which to study the cell. This instrument is called an electron microscope. Look on page 28 at the photograph showing blood cells as seen under the type of microscope your school has. It is called a light microscope, because you need a source of light to see with it. Now look at the photograph of the same cell as seen under an electron microscope. The light microscope made worlds visible which were not dreamed of before. The electron microscope lets scientists explore

these microscopic worlds more fully.

The future promises to be exciting. In your lifetime, scientists expect to learn more about the basic secrets of life. With this knowledge, perhaps they can prevent some of the diseases people now get. They may even be able to extend your life span by controlling aging. The possibilities are as limitless as man's imagination.



At the top are blood cells magnified by a light microscope. At the bottom you see *one* red blood cell magnified 18,400 times by an electron microscope. Compare these magnifications with those of cork cells on page 26.

PATHFINDERS IN SCIENCE

Severo Ochoa

(1905–) Spain

Arthur Kornberg

(1918–) United States

In 1959 a teacher and his former student shared the Nobel Prize in medicine and physiology. Severo Ochoa (oh-CHOH-uh), a professor at New York University, was the teacher, and Arthur Kornberg was his student.

What did the two men do? Dr. Ochoa made ribonucleic acid (RNA) (ry-boh-noo-KLEE-ik) in his laboratory, and Dr. Kornberg made deoxyribonucleic acid (DNA) (dee-AHK-see-ry-boh-noo-KLEE-ik). To understand the importance of their work, you first must know the story of the nucleic acids.

One of life's greatest mysteries has always been how a tiny fertilized human egg starting as one cell can grow into a human body with billions of different cells, many organs and functions, and the ability to reproduce. Scientists have traced the secret to the nucleic acids RNA and DNA, which are found in every cell.

Proteins are the building blocks of life. Nucleic acids (RNA and DNA) are the blueprint that determines the structure of the building blocks. RNA is found in the

On the left is a model of DNA. Its shape is that of a double *helix*. In the center are DNA molecules magnified 100,000 times by an electron microscope. At the top right is Dr. Severo Ochoa, and at the bottom right is Dr. Arthur Kornberg.

cytoplasm, around the nucleus of the cell, and DNA is found in the nucleus of the cell. Scientists believe that the nucleic acids are the key to the way in which living things are born with, or *inherit,* certain characteristics. RNA and DNA determine that baby whales look like whales and baby ants look like ants. RNA and DNA determine, among other characteristics, the color of the eyes and hair of every human baby.

Both DNA and RNA are in the shape of long chains. The chains are made up of certain molecules, and are twined around each other like a spiral staircase, or *helix*. DNA reproduces itself in a way that is described like this: Two chains of DNA fit together as a hand fits into a glove. They come apart. The hand then acts as a mold for the formation of a new glove and the glove acts as a mold for a new hand. Thus there are two gloved hands where there was only one before.

Scientists believe that the nucleic acids control the making of proteins in each organism. DNA is the master mold for passing heredity patterns from generation to generation. RNA is the copy used in the actual manufacture of proteins.

Dr. Ochoa and Dr. Kornberg were the first scientists to make test-tube models of DNA and RNA, models that resemble the real nucleic acids both physically and chemically. Their work provided other scientists with the means of probing further into the secret of life.

Using What You Have Learned

1. A magnifying glass is a lens. Because you hold it in your hand to use it, it is called a hand lens. Before microscopes could be built, lenses had to be made that would magnify many times more than your hand lens. High-powered lenses were first made about four hundred years ago. Some were used in making telescopes to observe the moon and planets. Some were used in making the first microscopes. A microscope has several lenses in it. Examine one to find out where they are located. Do you understand how a microscope works? Learn how to examine things under a microscope. Read *The Microscope and a Hidden World to Explore* by Irene S. Pyszkowski to find out how to use and care for a microscope.

2. Put bits of thread, hair, soil, and salt on microscope slides. Now look at them through a microscope. Compare their sizes under the microscope with their sizes under a hand lens.

3. Now look at strips of newspaper, aluminum foil, and cloth, a leaf, and the wing of a butterfly under your microscope. You should be able to see fibers in the paper and the cloth. Can you see the thin veins of the leaf? Why can you see the veins of the butterfly wing so clearly? How can you make the veins of a leaf easier to see under the microscope?

To see an object well under your microscope, light must pass through the thing you are looking at. The mirror at the bottom of your microscope reflects light from a window or electric bulb so light goes through the object you are observing.

4. Now repeat Robert Hooke's experiment. Ask an adult to use a single-edge razor blade to shave off a very thin layer from a piece of cork. Examine the cork layer with your microscope. You will see the little "boxes" or "cells" that Hooke saw.

Examining the Cell

You, a rosebush, a sparrow, an elephant, an ant, a snake, and a shark are made of cells. The cells that make up a rosebush are different from those that make up an ant. How do they differ? With the aid of a microscope, you can easily examine the kinds of cells that make up plants and animals.

OBSERVATION

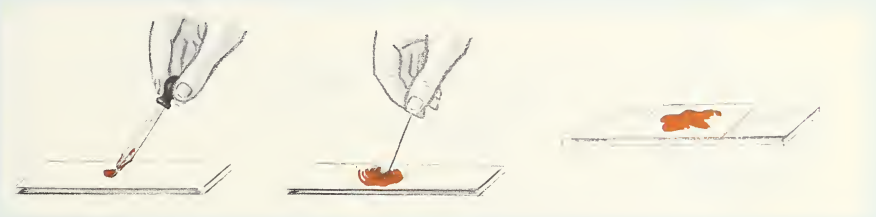
What Do Cheek Lining Cells Look Like?

What You Will Need

glass slide
cover slip
microscope
iodine thinned with water (1 part iodine to 2 parts water)
flat toothpicks
medicine dropper

How You Can Find Out

1. Place a drop of iodine in the center of a clean slide.
2. Scrape the inside of your cheek with the flat part of a toothpick.
3. Roll the end of the toothpick in the drop of iodine.
4. Place a cover slip over the iodine.
5. Look at the slide under the low power of your microscope.



Questions to Think About

1. What do you see?
2. Why were you told to add iodine to the water?
3. If you have high power on your microscope, use it to look at the cells. What do you see now?

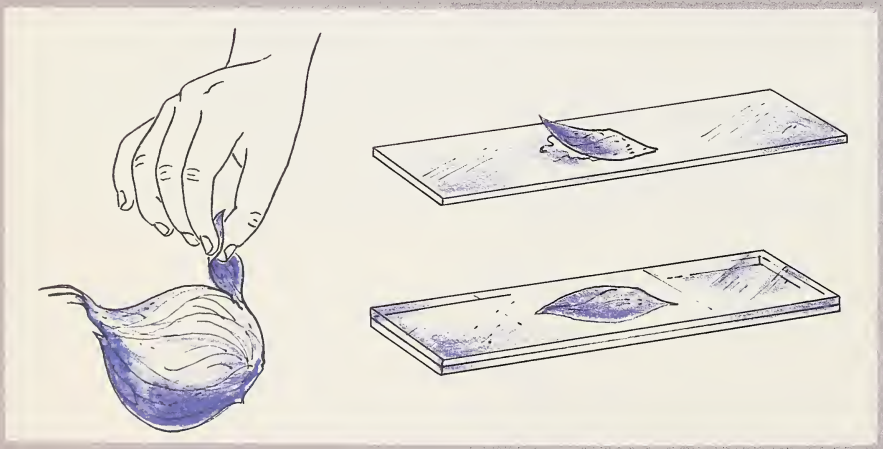
What Do Onionskin Cells Look Like?

What You Will Need

glass slide
cover slip
some iodine thinned with water
(1 part iodine to 2 parts water)
microscope
medicine dropper
onion

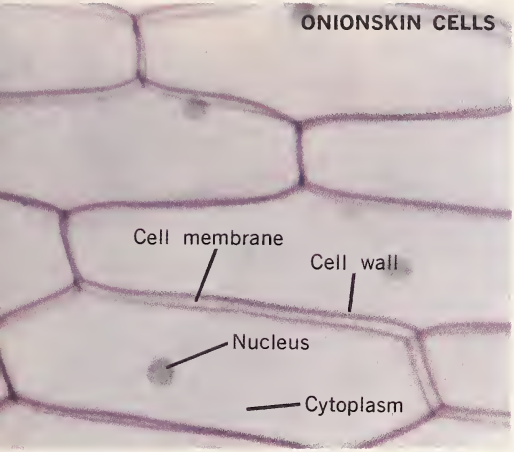
How You Can Find Out

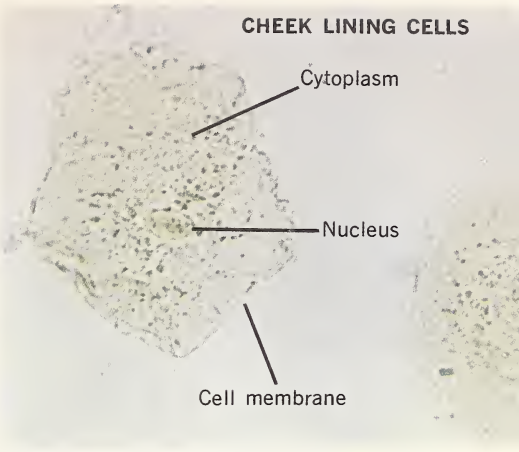
1. Place a drop of iodine in the center of a clean slide with the medicine dropper.
2. Gently pull the skin off a piece of onion.
3. Put the onionskin in the drop of iodine.
4. Place a cover slip over the drop of iodine.
5. Look at the onionskin first under the low power of your microscope, then under the high power.



Questions to Think About

1. What do you see?
2. Why were you told to add iodine to the water?
3. What do you see better under high power than you saw under low power?





Look at the cells from a plant and the cells from an animal. What do you see that is the same? What is different? Can you identify plant cells and animal cells without knowing the names of the living things from which they came?

Now that you have compared cells from an onionskin with cells from the lining of the mouth, can you tell the ways in which these cells are alike? Did you see a round object inside each cell? It is called the **nucleus.** The nucleus directs the growth and reproduction of the cell. In the space around the nucleus of the cell is the **cytoplasm** (SY-tuh-plaz'm).

Can you tell the ways in which these cells are different? Around the edge of the onionskin cell is a thick, firm wall called the **cell wall.** A plant's cell wall is made of **cellulose** (SEL-yoo-lohss), which is not living. Now look again at what looks like a thin line around the cheek cell. This part of the cheek cell is the **cell membrane** (MEM-brayn). The cell membrane is living material.

Animal cells do not have cell walls of nonliving cellulose. Animal cells have only a cell membrane. But plant cells have both a cell membrane *and* a cell wall.

The nucleus, cytoplasm, and cell membrane of a cell are alive. When Robert Hooke looked at the thin slice of cork under his microscope, he saw the cell walls of cork cells, but he did not see the nucleus or cytoplasm. Do you know why he saw only the walls of the cork cells?

The Shape of Cells

When you look at pictures of cells, such as those of onionskin and cheek cells, you may think that cells are flat like a sheet of paper. You may even get this idea when you look at cells through a microscope. But cells are not flat. What shape are cells?

Have you ever looked down from a tall building at the people below? If you have, you know that you do not see them as they really are. They look like flat objects moving along. Keep this in mind when you look at cells. Cells are not thin, flat objects. They are three-dimensional. They have length, width, and height like the cell shown in the picture below.

The model in the picture below shows a three-dimensional view of a cell.

What Cells Are Made Of

Scientists called biochemists have studied what cells are made of. They have found that a large part of a cell is water. However, in the water are minerals made up of elements such as sodium, calcium, and potassium. There are sugars, fats, and proteins in the water, too. These are made up of carbon, hydrogen, oxygen, nitrogen, and other chemical elements.

Some of the materials in living cells are dissolved in the water. To see what happens to materials when they are dissolved in water, mix a spoonful of sugar in water. What happens to the sugar crystals? Why can't you see them when the sugar is dissolved in water? When sugar crystals are mixed with water, they break up into smaller bits called sugar **molecules** (MOL-uh-kyoolz). Sugar molecules are too small to see. The sugar seems to disappear when its molecules are scattered throughout the water. You cannot even see them with a microscope.

Some of the materials in living cells, such as fats and proteins, are not dissolved in water. They mix with the water, but they do not dissolve.

If you put a spoonful of cooking oil in a jar of water, you will see that it does not mix with the water. However,

Shake the jar with oil and water. What happens? What happens when you stop shaking it?

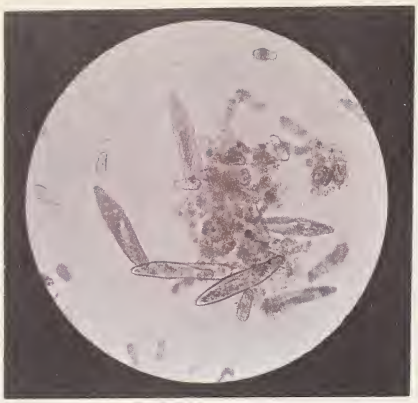
if you shake the jar hard for some time, some of the oil will break up into smaller bits. When you stop shaking it, they will collect again at the top of the water. If you had a way of breaking the oil into very small bits, they would stay scattered throughout the water. This is what happens when milk is homogenized. The butterfat in the cream is broken up into small bits that mix evenly throughout the water in the milk. They do not collect and come to the top of the milk as cream. If you put a drop of homogenized milk on a microscope slide, you can observe the small bits of fat with a microscope. They are not dissolved. Many of the materials in living cells are scattered in the same way as the butterfat in homogenized milk.

You could mix together all the contents of a cell in just the right amounts, but the mixture would not produce the living material of a cell. Scientists have been successful in making some parts of the living cell. Some day they may be able to make all of it. However, today only a cell can produce more living material. Or, to put it another way, only a cell can produce another cell.

Using What You Have Learned

Use a toothpick to examine the white of an egg. Note how thick and sticky it is. Most of the egg white is protein and water. The protein is not dissolved in the water. In this way, egg white is something like the contents of a cell.

Ameba



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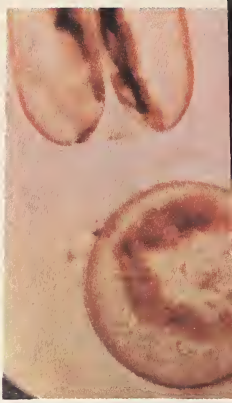


Diatoms

Each of these living things is only one cell. Which are plants? Which are animals?

From One Cell to Many Cells

All living things begin life as a single cell. But you know that you are made up of more than one cell. So are roses and elephants and most other plants and animals we have named. In fact, each of these living things is made up of many billions of cells. How, then, did they all develop from single cells?

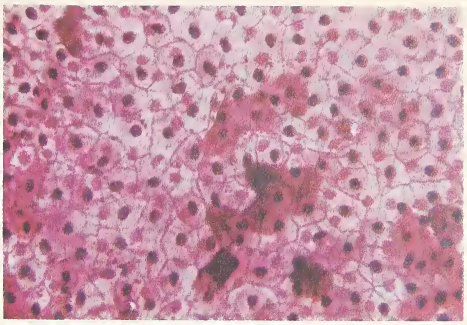
Each cell divided into two cells, the two cells into four cells, the four cells into eight cells, the eight cells into sixteen cells, and so on, until many billions of cells were produced. It is believed that an adult weighing 160 pounds has about 60,000,000,000,000 cells. That's sixty thousand billion cells —and all from one cell!

Similar Cells Make Up Tissues

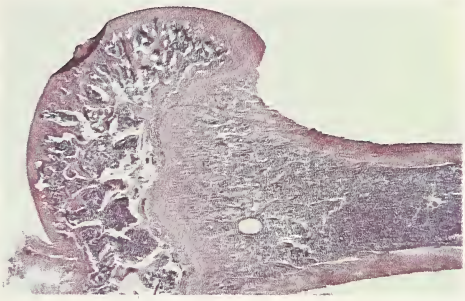
Some plants and animals, like diatoms and amebas, are made of only one cell. But most plants and animals have many cells. You are made of many cells. Some cells make up your bones, some make up your muscles, and some cells make up your skin. All bone cells look very much alike; so do all muscle cells.

All the cells that look alike are useful in the same way. All skin cells protect, all bone cells support, and all muscle cells move. Groups of similar cells are called **tissues** (TISH-ooz). Billions of cells make up your body, but all of these may be divided into five kinds of cells that make up your tissues.

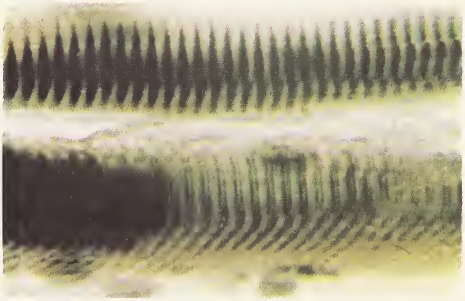
TISSUES OF THE HUMAN BODY



1. **Covering tissue.** This tissue covers the surfaces inside and outside your body. Skin cells make up the skin tissue that covers the outside of your body.

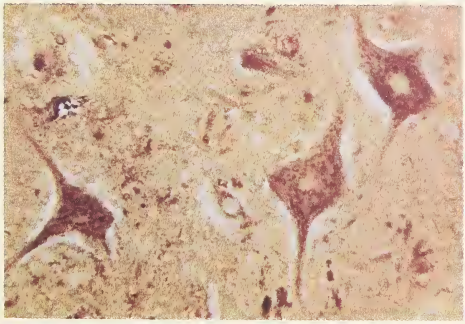


2. **Connective and supporting tissue.** This tissue supports your body and holds your cells and other tissues together. The cells of connective tissue spread among other cells and bind them together. Bone cells build bone and teeth.

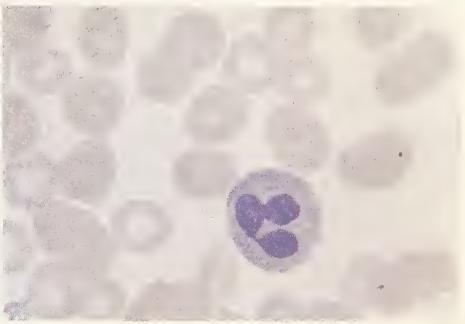


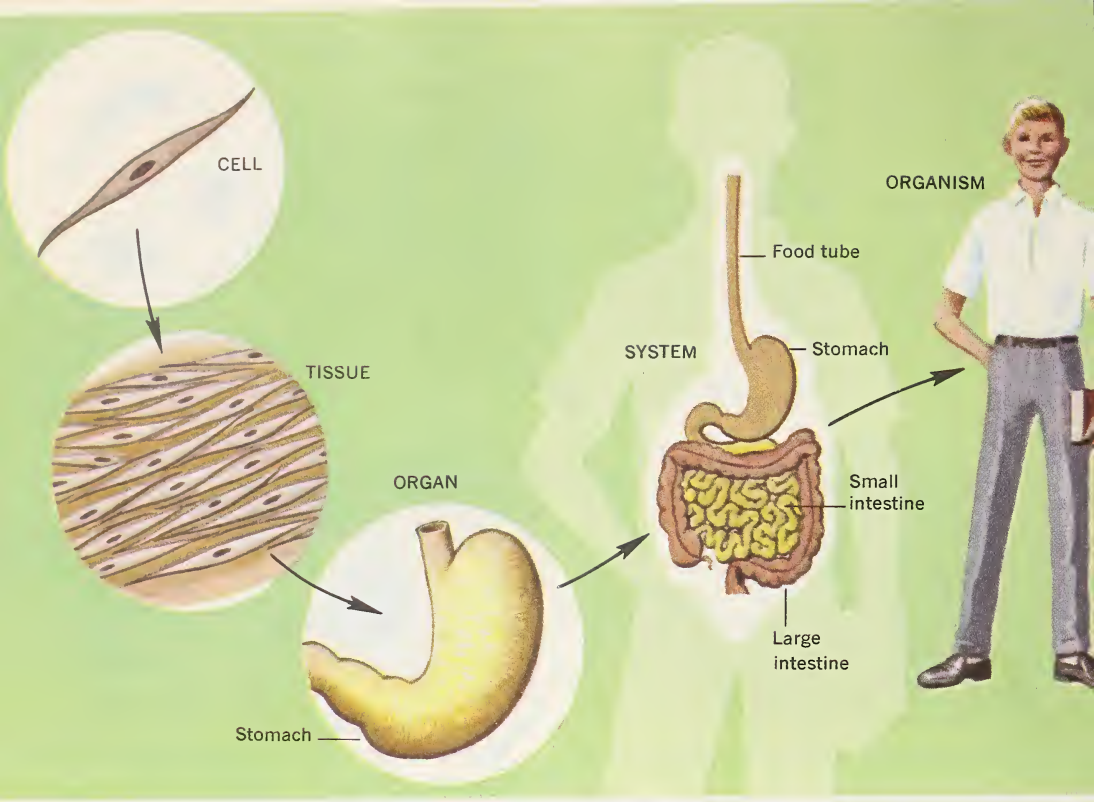
3. **Muscle tissue.** Your muscles are formed from muscle cells. You have three kinds of muscles: heart muscle, muscles of the food tube and blood vessels, and muscles that are attached to your bones, which enable you to move.

4. **Nerve tissue.** Your brain, nerves, and sense organs are made of nerve tissue. Nerve tissue carries messages from one part of the body to another.



5. **Blood tissue.** Blood is a tissue. Two kinds of cells in blood are red cells and white cells. Red cells carry food and oxygen. White cells fight disease.





How does this chart show the structure of an organism?

Tissues Make Up Organs

Tissues are groups of cells that work together. But one kind of tissue cannot work alone. Tissues are grouped together to form **organs.** Each organ is made of different kinds of tissues. Your heart is an organ. Your heart is made mostly of muscle cells held together by connective tissue. But you know that the heart also has blood tissue. And it has nerve tissue. Covering tissue lines the inside and covers the outside of the heart. All the tissues that make up the heart work together to pump the blood.

An organ is a group of tissues that work together. Cells make up tissues and tissues make up organs. You have many organs: eyes, ears, heart, brain, kidneys, lungs, intestines. What others can you name?

You have a brain, a spinal cord, nerves, and several sense organs (eyes, ears, nose, etc.). All these organs work together. With these sense organs you can see, hear, smell, taste, and feel. All these organs together make up a **system.** It is your *nervous* system. You have a nose, a windpipe, and lungs. These organs make up your breathing, or *respiratory*, system. You have a food tube which includes the stomach, small intestine, and large intestine. All these organs are a part of your *digestive* system. Another system in your body is the *circulatory* system. See if you can name the parts of your circulatory system.

Organized Living Systems

All the systems in your body work together. All animals and plants are **organized living systems.** Cells are organized into tissues, tissues are organized into organs, organs are organized into systems, and systems are organized into living systems called **organisms** (OR-gun-iz'mz).

You, a rosebush, a sparrow, an elephant, an ant, a snake, and a shark are all organisms. Even the one-celled ameba is an organism. Though it does not have tissues and organs, it is still an organized living system. All one-celled animals and plants are organisms. Every living plant and animal is an organism.

Using What You Have Learned

1. Build a three-dimensional model of a cell. Label the cell membrane, nucleus, and cytoplasm.

2. Place a cup of soil in a quart jar of water. Shake the jar until the soil is mixed with the water. Set the jar on a table and observe what happens. Which particles settle first? Why does the water remain cloudy even after most of the material has settled? In what way is this water mixture like the one in the cytoplasm of a cell? Examine a drop of the cloudy soil water with a microscope. Explain what you see.

WHAT YOU KNOW ABOUT

Cells, Tissues, Organisms

What You Have Learned

All plants and animals are made up of **cells.** Robert Hooke developed one of the first microscopes through which to see cells.

Two German scientists, Theodor Schwann and Matthias Schleiden, developed the **cell theory,** which states that all living things are made of cells and develop from single cells.

Every cell has a **nucleus,** which directs the growth and reproduction of the cell. The **cytoplasm** is the material around the nucleus of the cell. Around the cytoplasm is a **cell membrane.** A plant cell also has a **cell wall** around its cell membrane.

Much of a cell is water containing minerals, made of elements such as sodium and calcium. There are also **molecules** of sugar, fat, and protein in the water of the cell.

Groups of cells that work together are called **tissues.** There are five kinds of tissue: covering tissue, connecting and supporting tissue, muscle tissue, nerve tissue, and blood tissue. Groups of tissues that work together are called **organs.** The organs that work together are called **systems.** All the systems working together make up an **organized living system,** or **organism.**

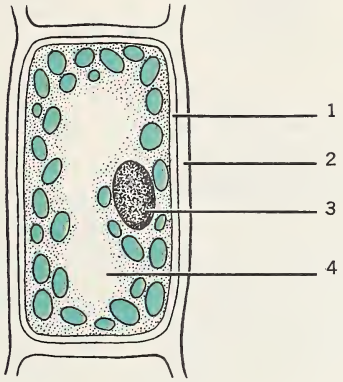
Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

cell membrane	cytoplasm	organism
cell theory	nucleus	system
cell wall	organ	tissue

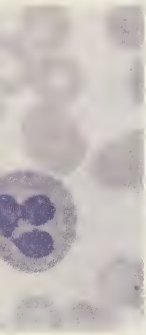
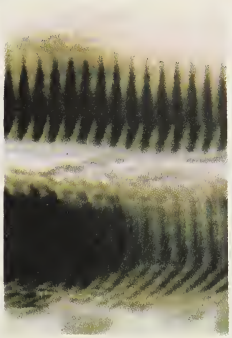
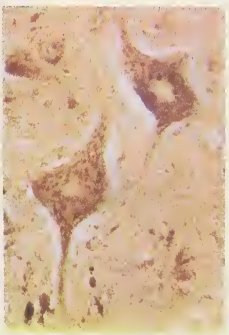
Name the Parts

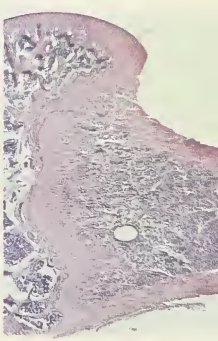
Look at the drawing of the cell. On a page in your notebook, write the name of each part that is numbered. Is this cell a plant cell or an animal cell? How can you tell?



Which Tissue?

1. This tissue covers the surfaces inside and outside your body.
2. Your sense organs are made of this tissue.
3. This tissue causes movement.
4. These tissues support your body.
5. This tissue transports foods and wastes into and out of cells.



YOU CAN LEARN MORE ABOUT

Cells, Tissues, Organisms

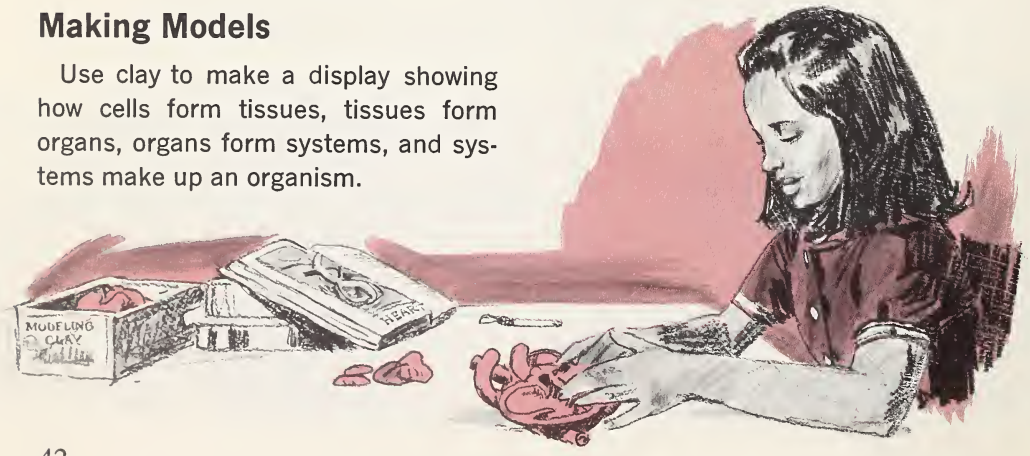
Unscramble the Letters

1. All living things are made of one or more cells or of cells and their products.
2. The part of the cell that directs growth and reproduction.
3. The material around the nucleus of the cell.
4. Tissues that work together.
5. The nonliving material of a plant cell wall.
6. Groups of cells that are useful in the same way.
7. Any living thing.
8. Organs that work together.

1. LELC RETOHY
2. LUNECSU
3. OCTMASLYP
4. GNOAR
5. SOLCEELUL
6. IUTSSE
7. MSIAGONR
8. YSTMSE

Making Models

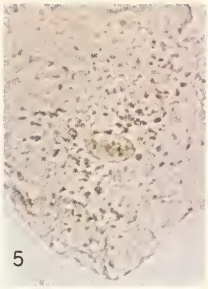
Use clay to make a display showing how cells form tissues, tissues form organs, organs form systems, and systems make up an organism.



What Is It?

Look at the pictures below and on the right. Copy the number of each picture in your notebook and next to it write whether the picture is of a cell, a tissue, an organ, a system, or an organism.

4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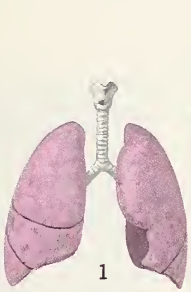
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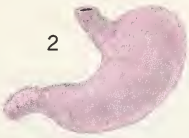
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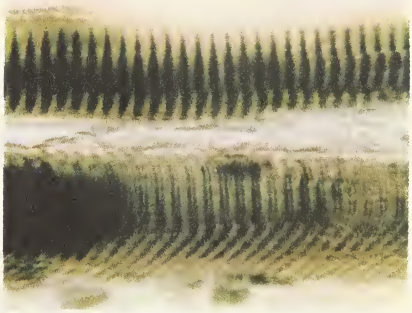
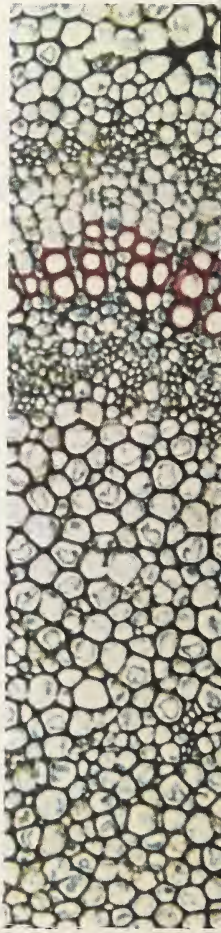

6

You Can Read

1. *Experiments with a Microscope,* by Nelson F. Beeler and Franklyn M. Branley. Many projects using a microscope are described.
2. *What Is a Cell,* by Fred M. King and George Otto. Tells about the structure of cells and their activities.
3. *Golden Book of Biology,* by Rose Wyler and Gerald Ames. Covers cell structure, heredity, and other topics.
4. *The Science of Life,* by Lois and Louis Darling. An advanced book that covers the life processes.



3

Growth and Development

How Animals Grow
How Plants Grow
Human Growth

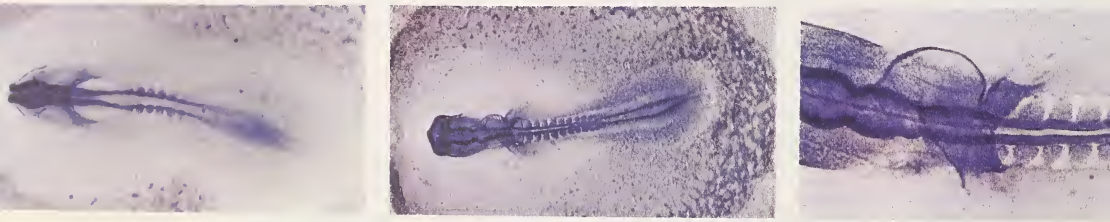
You, a rosebush, a sparrow, an elephant, an ant, a snake, and a shark grew and developed from single fertilized egg cells. All animals with backbones, and most others, begin as single egg cells. Flowering plants also begin as single egg cells. In this unit you will learn how living things grow and develop.

How Animals Grow

The series of pictures below shows the way one animal grows from a single fertilized egg cell. Many animals develop in the same way. However, the amount of time it takes for them to develop fully differs. Follow the pictures in order. What do you see happening as the cells divide?

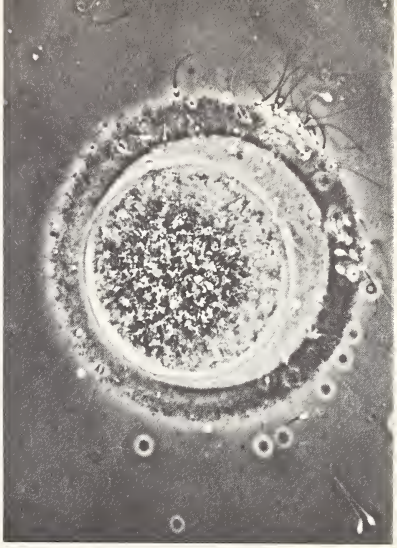
These photographs show the first 16 to 23 hours in the life of a chick.

After 24 hours the brain is seen forming. On the right is a view of the heart.



After 36 hours the chick begins to twist. Note that the eye lens is formed.

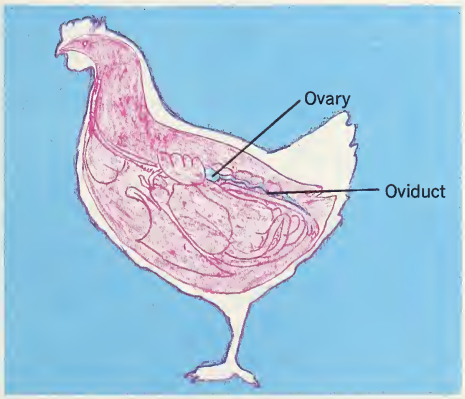
You have seen that a chick begins its life as one cell. The egg cell of a chicken is large compared with the egg cells of many other animals. For this reason it is easy to examine the egg of a chicken. Crack open a chicken egg. Look at the yellow part, or **yolk,** of the egg. Do you see a white spot on the surface? This small spot becomes the chick **embryo** (EM-bree-oh). This part of the egg contains the nucleus of the egg cell. The egg cell will not develop into a chick embryo unless it is **fertilized** (FER-t'l-yzd).



The sperm cells have tails that enable them to swim. Note size relationships.

How the Egg Cell Is Fertilized

The egg cell is produced in the **ovary** (OH-ver-ee) of the hen, as you can see in the diagram. If your mother buys a whole hen with its insides intact you may be able to find many egg cells in it. The egg cells are attached to the ovary by very thin stalks. The ovary is on the left side of the hen. The cells attached to the ovary are very small. All you can see are the yellow yolks. Look for them next time your mother buys a hen. Be sure to look before she cooks it. As the egg cell passes through a tube in the chicken, called the **oviduct** (OH-vih-dukt), the white is added.



But before the egg can develop into a chicken, it must be fertilized. Fertilization occurs when special cells from the rooster called **sperm cells** reach the egg cells. The picture above shows the size of a sperm cell compared to the size

Here is a picture of rooster sperm as seen under a microscope.

of an egg cell. Notice how very small the sperm cell is. Can you give a reason for the large size of the egg cell?

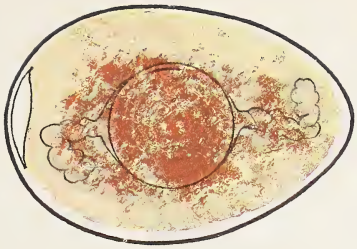
The largest part of a sperm cell, called the *head,* is the nucleus. The rest of the sperm cell is made up of a long slender tail that enables it to move to the egg cell. When a sperm cell reaches the nucleus of an egg cell, the nucleus of the sperm cell joins with the nucleus of the egg cell. The egg cell is then fertilized. When do you think this takes place — before or after the shell is formed around the egg? Give a reason for your answer.

Incubating Eggs

What happens after a fertilized egg is laid by a hen? Nothing much will happen unless the egg is kept at a temperature of about 103° F. At this temperature, the fertilized egg will develop into a chick. Hens cover the eggs with their bodies to keep the eggs at this temperature. The eggs may also be kept in special containers, called **incubators** (ING-kyoo-bay-terz), in which the temperature can be controlled.

It takes twenty-one days for a chick to develop from a single fertilized egg cell. This time period is called the **incubation period.** During the incubation period, many things take place inside the shell. At first the single cell divides many times. The new cells form a ball on one side of the yolk. The yolk itself does not divide. With what does the yolk provide the egg?

These girls belong to a science club whose project is to study the development of the chick.



Notice how the egg is held in place within the shell. Where is the embryo located?

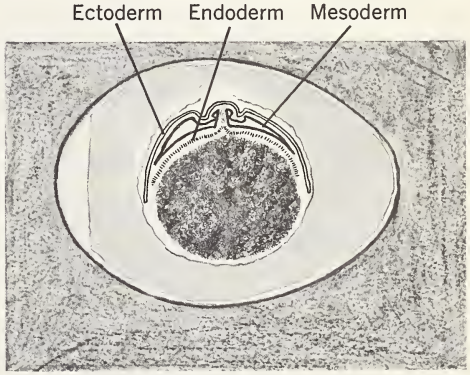
Biologists who study animal development have carefully noted what happens after an egg cell is fertilized. They have made many observations with microscopes. They have kept records, including photographs, of each stage of development. From these records, accurate and detailed descriptions of what happens have been prepared.

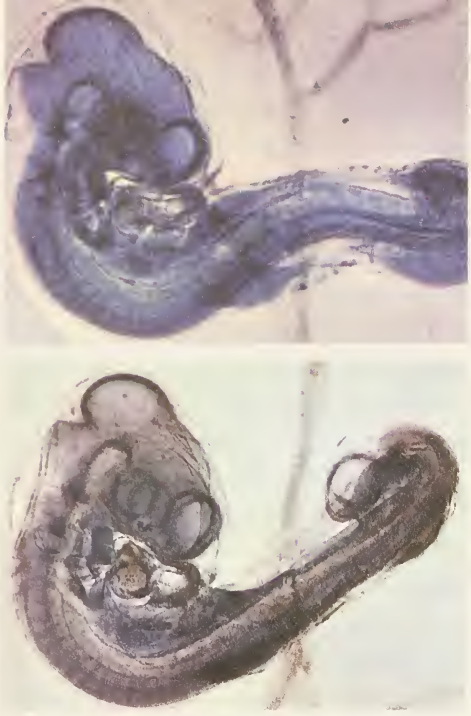
Some day you may study the science of the early development of living things. It is called **embryology** (embree-OL-uh-jee). Can you tell why this science is called embryology?

The Development of a Chick

Soon after the ball of cells forms inside the egg cell, it looks pushed in on one side. You can see in the diagram on the right that when this happens, three layers of cells are formed. Embryologists have given each of these layers a name. The name tells where the layer of cells is located. The **ectoderm** (EK-tuh-derm) is the outside layer. The **endoderm** (EN-duh-derm) is the inside layer. The middle layer is called the **mesoderm** (MESS-uh-derm).

The cells making up each of these three layers divide, grow, and change to become different parts of the chicken's body. The outer skin, feathers, brain, and nervous system are formed from cells in the ectoderm. The lining of the digestive tubes and breathing tubes is formed from cells in the endoderm. Endoderm cells also form the glands of the body. Cells from the mesoderm produce the lower skin layer of the chick, the organs of the circulatory and excretory systems, and the muscles, bones, and cartilage.





After 3 days (top picture) the tail and limb buds can be clearly seen. Eyes and ears can be seen, as well as regions of the brain. After 4 days the circulatory and nervous systems are also well along in their development.

If you have an incubator in your school, you can incubate chicken eggs and observe their development. Be sure to use fertile eggs. You can get fertile eggs from a chicken hatchery. Can you tell why eggs sold in stores usually are not fertile? If you do not have an incubator, you can get incubated eggs from a chicken hatchery. These will hatch shortly into chickens.

The photographs on page 46 show chick embryos at different stages of development. After a fertile egg has been incubated for 48 hours (two days), you can see the embryo's heart beating. You can also see how blood vessels cover the yolk. The yolk provides food for the embryo. The blood picks up food from the yolk and carries it to all parts of the embryo. The photographs on the left show developing parts of the chick embryo. See on this page and on page 46 how the embryo grows and develops from 16 to 96 hours.

If you have an incubating egg, you can observe the growth of a chick embryo yourself. It is possible to cut both the shell and the outer membrane away from the flatter end of the egg. The inner membrane must be painted with melted vaseline so that you can see through it and so that the growing embryo inside is protected. Take the

egg out of the incubator for a short time each day to observe the changing embryo.

Perhaps the most exciting development during the incubation period is the movement of the embryo inside the shell. The chick does not lie quietly before it hatches. Its movement, or behavior, starts before birth. This is true of many animals other than the chick. Kittens and puppies are active inside the mother before they are born. So are human beings.

How Behavior Develops

Embryologists, who have studied embryos of many different animals, have arrived at some ideas about how behavior develops. Look for some of these things as you observe the growing chick.

One idea is that development begins with the head and proceeds toward the tail. You will see in your chick embryo that the head looks like a head before the tail looks like much of anything. You will also see the first movements at the head end—a lifting and lowering of the developing head. Can you find evidence of a head-to-tail direction of development after birth? Look at some very young babies. How does the size of the head compare with the total length of the baby? How does the length of the legs compare with the baby's total length?

Another idea you may note as you watch the growing chick is that movement creates movement. One movement sets off another. The heartbeat is visible after the second day. It looks like a powerful beat for the size of the

How does this picture show evidence of the head-to-tail direction of development?

embryo. The throbbing of the heartbeat stimulates the head end and starts the rhythmic bobbing we have described.

Behavior and Environment

A fascinating thing is the way in which behavior changes as the environment changes. As the chick grows, the head gets bigger and heavier. The neck gets longer, but it stays slender. The head-bobbing then changes to a sideways motion. Another early movement is the twisting of the rest of the body. When the embryo gets too big for such activity within the shell, the movement gradually becomes a jerking one.

Perhaps the most important idea is that all of the movements the chick can make at birth have a long history in the egg. Newborn chicks can peck, but they have been practicing pecking movements almost from the beginning of life. Preparation for pecking started with the opening and closing of the beak at six days of embryonic life. By the seventh day, the embryo begins to thrust its beak forward, as if pecking. Wing and leg movements start before birth. Wing-buds and leg-buds move forward, backward, and sideways during the first ten days in the shell.

How did the newborn chicks peck their way out of their shells?

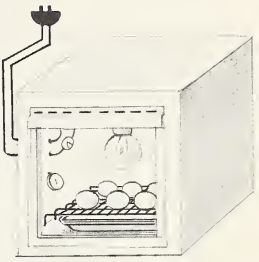
By the twenty-first day, the chick is fully formed and ready to hatch. Its muscles and nervous system have developed enough to enable it to peck a hole in the shell, stretch its body, break open the shell, and tumble out. A few hours later, the little chick's feathers are dry, and it can walk. The chick can get its own food and does not have to be fed by its mother, as do some other animals.

The various stages in the development of a chick from a fertilized egg cell are the same for all chickens. They are the same for all birds. In all cases, one stage of development follows the other in an orderly pattern. Scientists now believe that the nucleus of the fertilized egg cell has in it the "blueprint" for this orderly pattern of development.

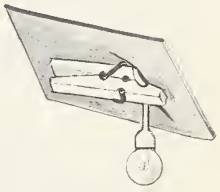
Using What You Have Learned

Your class can make its own incubator to observe the growth and development of chicken embryos:

a. You will need two cardboard cartons: one about 10 by 10 by 15 inches and the other about 12 by 12 by 17 inches or larger. You will also need a socket, a bulb, lamp cord, asbestos paper 10 by 10 inches, aluminum foil, a wall thermometer, and a thermostatic switch, which you can get at a hardware store. Someone can probably bring an aluminum cake pan about 7 by 9 inches and wire mesh about 11 by 13 inches from home. The mesh must be large enough to fit the floor of the small box with enough overlap to fold under to make a platform. This platform will hold the eggs over the cake pan.

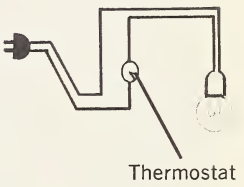


b. Cut one end off the small box. Cut a large window in the side of the large box to fit against the open end of the smaller box.



c. Suspend a light bulb from a hole in the top of the smaller box. Do this with a clothespin, as in the diagram. Put a piece of asbestos paper above the light. Have your teacher connect the thermostat, as shown in the diagram.

d. Next fit a pane of glass over the window opening. Make sure you tape all the edges for safety. Make a hinge for the window by using a double thickness of 2-inch adhesive tape. Staple the hinge to the box. Bend the wire mesh to fit above the cake pan. Put water in the cake pan.



e. Attach the thermometer and thermostat to the inside of the smaller box. Line the box with aluminum foil to reflect the heat toward the eggs. Pack crumpled newspaper between the two boxes for insulation.

f. You will have to try different-sized light bulbs until you find one that keeps the box at about 103° F. To regulate the heat level, make three or four 1-inch holes plugged with corks. You may remove these or insert them to regulate the heat level.

g. You are now ready to put in a dozen fertilized eggs. At the end of three days, remove an egg and examine its contents. See pages 50-51 for how to do this. Do this every three days for twenty-one days. Take notes and draw pictures of what you see.

How Plants Grow

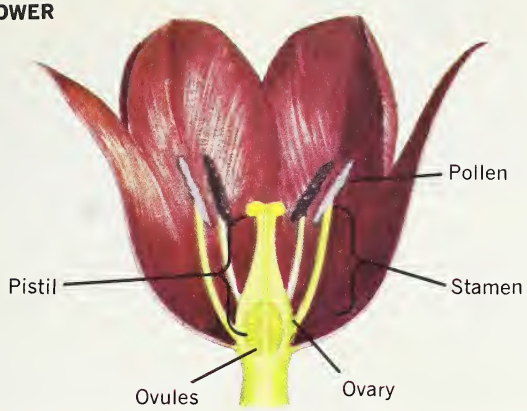
Biologists have studied animals that lay eggs, such as birds, frogs, and fish. They have studied mammals—that is, animals that bear live young—such as humans, cows, and pigs. Their research has led them to believe that all living things go through an orderly pattern of growth and development.

You have studied how a chick develops. Now you will see how plants grow and develop. You will learn how plants develop by studying a seed.

Identify the seed coat, the stored food, and the undeveloped plant. Check your answers.

What is a seed? Examine a lima bean seed that has been soaked in water overnight. Why should the lima bean be soaked in water? Seeds soak up a great deal of water, swell, and get soft. This makes them easier to examine. Cut open a seed. What covers the outside of the seed? What is underneath this covering? How is the underneath part different from the covering? What is it used for? What do you find between the two main halves of the seed?

PARTS OF THE FLOWER

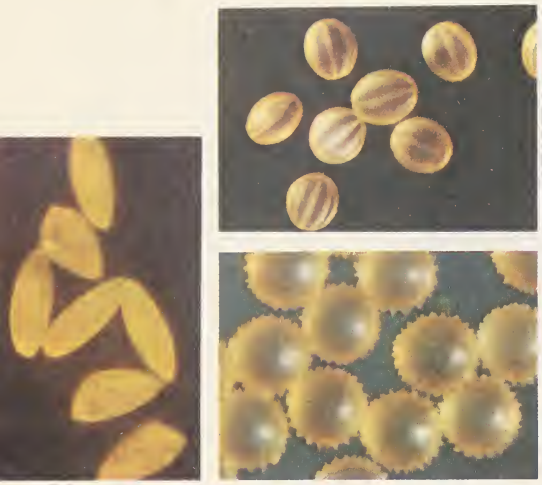


When you have answered these questions, you will have located the three main parts of a seed: (1) the seed coat, (2) the stored food, and (3) the undeveloped plant. But how is a seed formed?

The Beginning of a Seed

The drawing above shows the parts of the flower that make the seed. Look at some flowers such as lilies, gladioluses, petunias, or tulips. Remove the petals and examine the parts shown on the drawing. The small, stalklike parts around the tubelike part in the center are called the **stamens** (STAY-munz). On top of each stamen is a powdery material, called **pollen.** With a toothpick, pick off some of this material. Examine it with a magnifying glass. If you have a microscope, you can see it much better. You will find, when you examine pollen, that pollen is made up of very small bits, called pollen grains.

Now examine the tubelike part in the center of the flower. This part is called the **pistil.** Touch the end of it with your pencil. It is sticky. Now follow the pistil down to where it is attached to the flower. Notice that the pistil is thicker there. This part is called the **ovary.** Carefully cut open the ovary with a sharp knife. You will see little white specks inside the ovary. These are called **ovules** (OH-vyoolz). Some of them will become the seeds after something else happens.



Here you see pollen from three different plants —lily (top), bergamot (left), and squash (right).

Trace the path of the pollen grain after it lands on the sticky surface of the pistil.

You know that all living things are made up of cells. You also know that the nucleus is an important part of the cell. In order for most new living things to begin, the nucleus of one kind of cell must join with the nucleus of another kind of cell. In chickens, the sperm nucleus joins with the egg cell nucleus. In flowering plants, nuclei of cells produced by pollen grains must join with nuclei of the ovule cells for fertilization to take place. *Nuclei* means more than one nucleus.

When pollen grains land on the sticky part of the pistil, they begin to grow. They form long tubes which grow right down the center of the pistil until they reach the ovules in the ovary. When a pollen tube enters an ovule, the sperm nucleus joins the nucleus of an egg cell in the ovule. When this happens, the egg cell is fertilized. The fertilized egg now begins to divide. Cell division and growth continue until a small, undeveloped plant is formed. Because it is undeveloped, the plant is called an embryo plant.

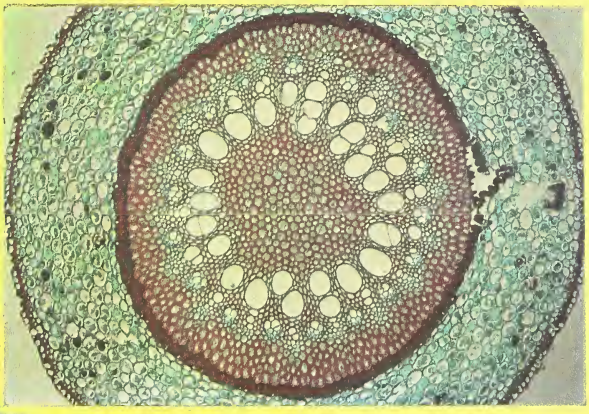
The flowers of various kinds of plants look quite different. For example, the flower of a bean plant looks quite different from the flower of a tulip. But they both have stamens and pistils. Stamens and pistils are the seed-producing parts of the flower.

The Development of a Seed

When the egg cell is fertilized, it is one small cell. From this cell, a full-grown plant with roots, stems, and leaves develops. How does this remarkable development take place?

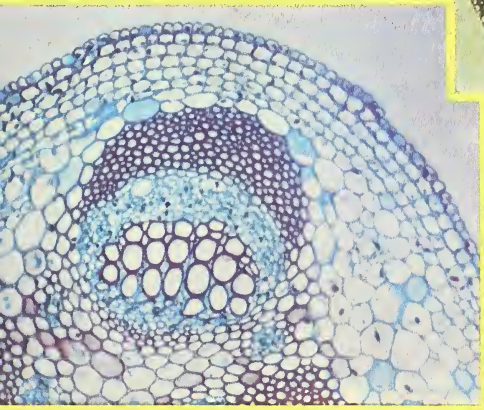
Look at the cells in the pictures below. In terms of their appearance, how many different kinds of cells can you find in the leaf? How many can you find in the stem? In the root? How are the cells arranged?

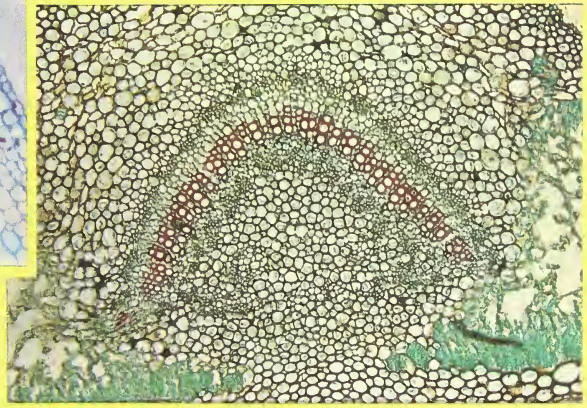
KINDS OF PLANT CELLS



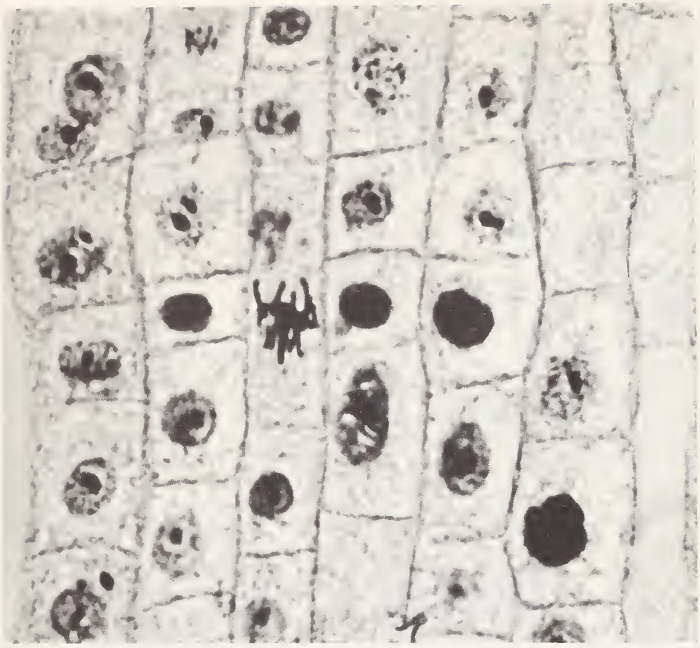
Root cells

Stem cells





Leaf cells



This is an onion root tip. Many cells are in the process of dividing. What do you see happening as they divide?

These different types of cells developed from one fertilized egg cell. When the fertilized egg divides, it forms two cells. The two cells divide to form four. The four divide to form eight cells. And so it goes, until the millions of cells making up the embryo plant within the seed have been formed. But something more takes place.

To get an idea of what happens, try this. Cut a piece of notebook paper into two parts. Now cut each of these parts into two. Continue cutting until you have sixteen parts. If you put all sixteen parts back together again, how large a piece of paper would they make? Suppose a fertilized egg cell produced, by cell division, sixteen cells. How big would each cell be? To produce the embryo plant in a seed, something more than cell division must take place. Actually, three things happen.

First, the new cells produced by cell division grow. They grow by taking in water and food materials from other cells in the plant. Many of the new cells become quite large. Second, some of the new cells change shape to form dif-

DEVELOPMENT OF A BEAN PLANT

ferent parts of the plant. Some change to become the cells of the roots. Some change to become cells of the stem. Others change to become the different kinds of cells in the leaves. And, finally, a third important thing happens. The cells become arranged into the pattern of an embryo plant.

Look at the diagram of an embryo bean plant. The plant in this diagram is larger than an actual embryo plant taken from a bean seed. But all embryo bean plants have this pattern. As you can see from the diagram, one part of the embryo develops into leaves and stem and another part develops into roots. This development, called **germination** (jer-muh-NAY-shun), takes place after the seed is planted. Some seeds, such as pea seeds, germinate soon after they are formed, even while they are in the pod. Have you ever found grapefruit or orange seeds that have germinated in the fruit? Some seeds, such as those of the Kentucky coffee bean, may be in the ground for many years before they germinate. Desert seeds germinate only after a rainfall.

How Does a Bean Seed Germinate?

What You Will Need

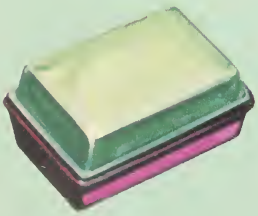
2 dishes or bowls 12 paper towels 12 lima-bean seeds

How You Can Find Out

1. Arrange three double layers of paper towels in the bottom of a deep dish or bowl.
2. Soak the paper towels with water by pouring water into the dish.
3. Lay twelve seeds on top of the wet paper towels.
4. Lay three double layers of paper towels over the seeds and dampen the top towels.
5. Cover the dish with another dish to reduce evaporation of water. We will call these dishes germination dishes.
6. Observe the seeds once or twice a day. As soon as they begin to grow, open one of them.
7. Carefully examine the plants each day. Keep a record of their appearance and size.
8. Compare the size of one of the plants—after roots, stem, and leaves have formed—with the size of a dry seed.

Questions to Think About

1. At the end of the first day, how can you tell that the seeds have taken up water?
2. What is the first sign that the embryo is growing? Which part pushes out of the seed first?
3. What happens to the two halves of the bean seed?
4. How long does it take for little roots to form along the side of the main root?
5. How long does it take for leaves to form?
6. How large is the largest bean?
7. Do all the seeds germinate? If not, what might have happened?
8. What will happen to the plants if they all remain in the dish without pruning?



Do Different Kinds of Seeds Germinate at Different Times?

What You Will Need

10 radish seeds	10 bean seeds	10 corn seeds
10 pea seeds	2 germination dishes	16 paper towels

How You Can Find Out

1. Prepare your germination dish as in the activity on page 60.
2. Place the seeds in groups according to kind on the moist towels in your dish and cover them with moist towels. Cover the dish with another dish.
3. Observe daily and record how many seeds have germinated.

Questions to Think About

1. Which kind of seed germinates first? Which kind takes longest?
2. Why do different seeds have different germination times?

How Does a Bean Plant Grow?

What You Will Need

pot or can of soil 10 bean seeds

How You Can Find Out

1. Plant the bean seeds about one inch apart and water daily.
2. Observe the pot daily and keep a record of your observations.
3. When the first plant begins to appear above the soil, carefully remove the entire plant from the soil and examine it.

Questions to Think About

1. Which part of the bean embryo comes through the soil first?
2. What has taken place beneath the soil when this happens?
3. How long does it take before the attached halves of the bean seed disappear?

Getting Food for Growth

A single fertilized egg cell requires certain materials to grow and develop into a many-celled complex organism, such as a tree, a chicken, or a human being. Food supplies these materials. You will recall that the chick embryo gets its food from the egg yolk. The embryo plant in a seed gets its food from materials stored in the seed. The human embryo gets its food from its mother's body.

Some insects and other animals have another way of getting food as they develop from a fertilized egg. The fertilized eggs of these other animals do not develop directly into little animals that look like the adult that laid the eggs. They first develop into an animal called a **larva** (LAHR-vuh) that looks like a worm.

The moth is an example of this type of animal. As you know, the eggs of a moth develop into caterpillars. The caterpillar is a larva. When a moth egg hatches into a larva, it is very small. But the larva immediately begins to eat leaves and other foods. During the

The orange-striped oak worm lays its eggs on oak leaves. When the eggs hatch, the caterpillars have a ready source of food. About a month later, the caterpillar spins a cocoon around itself. This is the pupa stage. What comes out of a cocoon?

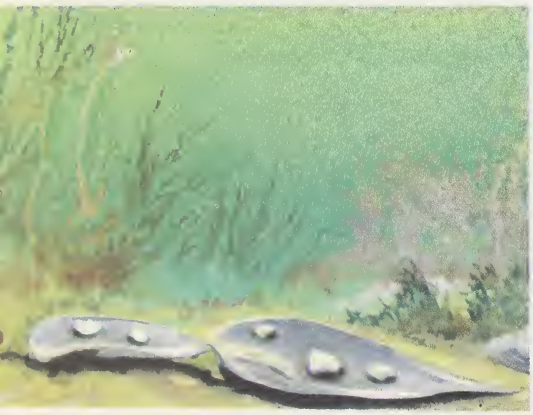
The three stages of a frog are egg, tadpole, and adult. How does the tadpole get its food? Where does it live? How does the adult get food? Where does it live? What physical change marks the point at which the frog is considered an adult? About how old is the frog when this change occurs?

time it is a larva, it eats a great deal. Its body gets larger and larger, and soon it spins a case or cocoon around itself. It is then called a **pupa** (PYOO-puh). While the pupa is in the cocoon, great changes take place. Almost all the organs of the larva are changed. The new moth develops from small clumps of cells in the pupa. As these cells grow and develop, they use as food the materials that were a part of the larva's body.

You have probably seen tadpoles. A tadpole is the fishlike stage of a frog.

A tadpole is very small at the time it hatches. But it grows as it finds food by swimming around in the water. Slowly, the tadpole's body changes into the body of a frog.

An oyster is another animal that has a larval stage of development. Within twenty-four hours after the oyster egg has been fertilized, it produces a larva. At first the larva is so small you need a microscope to see it. The larva feeds on microscopic plants as it swims about in the water. In fifteen days it has grown to about the size of the period at the end of this sentence. Then the larva attaches itself to a rock or an old oyster shell at the bottom of the water and continues to eat microscopic plants. It grows, forms a shell, and becomes a fair-sized oyster in about two years.



PATHFINDERS IN SCIENCE

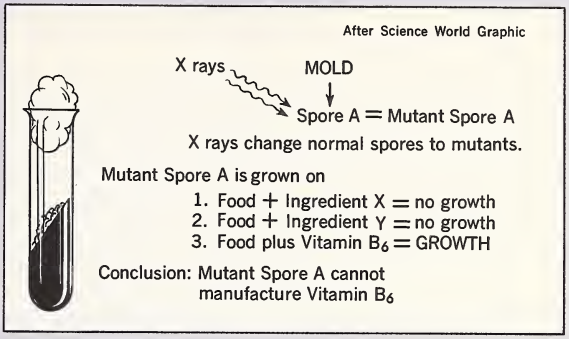
George W. Beadle

(1903–) United States

Like many other great scientists, Dr. George Beadle owes much to a teacher. "I thought I was going back to the farm," Dr. Beadle says, "but Miss Bess McDonald had a great ability to encourage her students to go ahead. She talked me into going to college."

Miss McDonald sparked a flame of enthusiasm for science in young George Beadle. She encouraged him to study at the University of Nebraska. There he became interested in *genetics,* the science of heredity. Genetics deals with such problems as why certain people are tall and others short and why different kinds of flowers are some colors and not others. Genetics deals with the problems of why living things are born, grow, and develop the way they do.

Dr. Beadle thought that one could come closer to finding answers in genetics by observing chemical changes one at a time in a simple organism rather than by observing numerous chemical changes in a complex plant or animal. He believed, for example, that tallness or shortness in a living organism might be the result of many chemical changes. He sought to study an organism


After Science World Graphic
X rays
MOLD
Spore A = Mutant Spore A
X rays change normal spores to mutants.
Mutant Spore A is grown on
1. Food + Ingredient X = no growth
2. Food + Ingredient Y = no growth
3. Food plus Vitamin B_6 = GROWTH
Conclusion: Mutant Spore A cannot manufacture Vitamin B_6

in which a change would be due to only one chemical reaction.

Dr. Beadle, working with Dr. Edward Tatum, found an almost perfect "guinea pig"—the red bread mold, which has the scientific name *Neurospora crassa*. One spore of *Neurospora* produces a great amount of mold all with the same characteristics. All that *Neurospora* needs to live is mineral salts, sugar, and biotin.

The two scientists X-rayed the mold. Their goal was to create offspring that differed from the normal mold in a simple chemical way. After exposing the spores to X rays, they gathered those spores formed by mating and placed them in a solution of mineral salts, sugar, and biotin. Some grew normally, others died, and a few began but did not continue to grow. Using a microscope, the two scientists carefully sorted out the spores that began to grow but for some reason did not continue. They sought the reason. After 209 experiments, they found that the reason these spores did not grow was that they were missing vitamin B_6. When these spores were mated with a normal strain, the need for vitamin B_6 was passed on to the offspring.

Beadle and Tatum had found that X rays changed the mold. This change made the mold unable to grow without outside help. The mold's need for vitamin B_6 was very much like a diabetic's need for the insulin that his body cannot produce.

The two scientists continued experimenting. Soon they had a great many molds that needed an extra nutrient or other kind of chemical. They had taken a big step forward in learning more about the growth and development of living things. Their success with *Neurospora* also provided *geneticists,* scientists who study genetics, with new techniques for using molds and other small organisms as tools to probe further into the growth and development of living things.

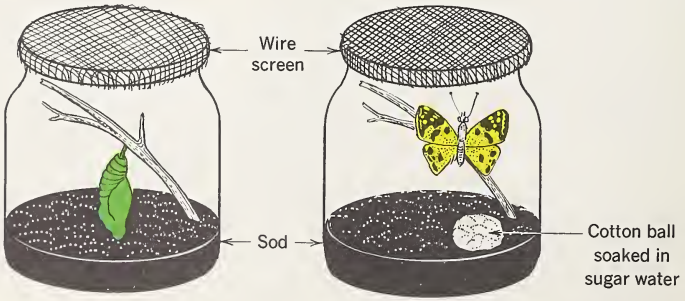
Using What You Have Learned

1. You can watch frogs' or toads' eggs develop into tadpoles. Frogs' and toads' eggs can be found wherever frogs live. The eggs are usually laid in early April. Frogs' eggs are found lying in bunches in ponds. The toads' eggs are laid in long strings. Collect the eggs in large pails and take plenty of pond water with them. In the classroom or at home, keep the eggs in gallon glass jars or other large containers. Do not put the eggs in an aquarium that contains fish. The fish may eat the eggs or the young tadpoles.

Use a magnifying glass to observe the hatching eggs. Take notes and draw pictures of what you see.

2. Collect some cocoons and **chrysalids** (KRISS'l-idz) during the fall and winter months. A chrysalid is what a butterfly spins around itself. Only moths spin cocoons. Put the cocoons or chrysalids in a quart jar with sod on the bottom. Cover the top of the jar with screen or netting. Keep the sod moist. Suspend the cocoons or chrysalids in midair from a thread or twig.

When the insect appears to be emerging, remove the cocoon or chrysalid to a jar large enough for the insect to spread its wings to dry. When the insect has emerged, add to the jar a cotton ball soaked in sugar water. What happens?

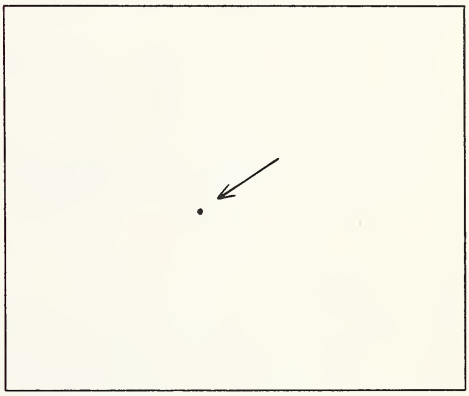


Human Growth

When you were born, you came into the world as a live baby. All animals that begin with an egg cell—elephants, rabbits, robins, whales, deer—come into the world as live babies. However, they do not start as babies; they *grow* to be babies. It takes a lot of growing to develop from an egg cell to a baby. You have probably looked at newborn babies and thought, "They seem so small." But when you began your life you were much smaller than a newborn baby. Look at the tiny spot in the picture. The spot is more than ten times larger than the egg cell with which your life began.

It may be difficult for you to realize that you started life as a single fertilized egg cell. Your development as an embryo was in some ways similar to that of the chick, except that the egg from which you developed was many times smaller than a hen's egg. It was about 1/100 of an inch wide. A microscope or a good hand lens would have been needed for you to see it.

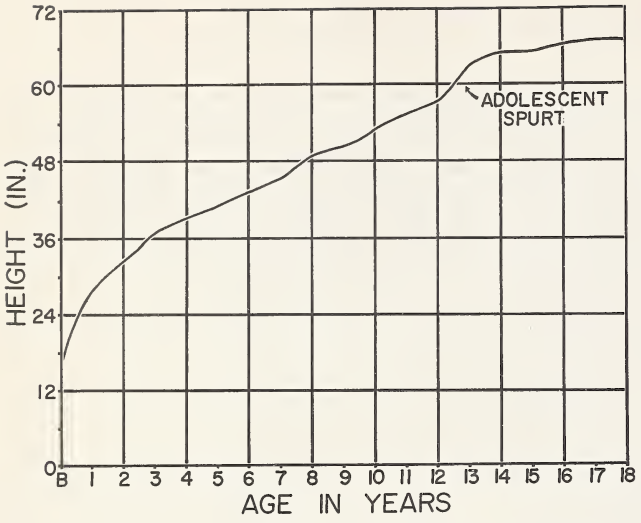
For a single fertilized egg cell to develop into a many-celled organism, food materials are needed. In the human egg, unlike the chicken yolk, there is very little food. As you developed, you got food from your mother's body. The human embryo has its own blood system, separate from the mother's, and there is never a direct flow of blood between mother and young. The blood



The fertilized egg from which you developed was 1/10 the size of the dot in the picture.

systems of the two are separated by thin tissues made up of cells that allow an exchange of oxygen, food, and wastes.

It took two months for the different parts of your body to form. At that time, you were about one inch long. During the next seven months, you grew about 18 inches. In fact, before you were born, you grew more rapidly than you will grow during any other nine-month period in your life.



This graph shows one person's growth for 18 years. Make such a graph for yourself with your parents' help.

Growing Tall

People continue to grow until they are about twenty-five years old. However, people grow more rapidly during some periods than they grow during other periods.

The graph above shows the **rate of growth** of one person. The numbers running up the side of the graph stand for inches of height. The numbers across the bottom of the graph stand for years of age. During which years was his growth most rapid? During which years was it least rapid? At what age did he reach his full height? If your family has a record of your height measured at different ages, you can make a graph like this one to show your rate of growth.

The rate of growth is the amount that something grows in a certain time. Different parts of a person's body grow at different rates.

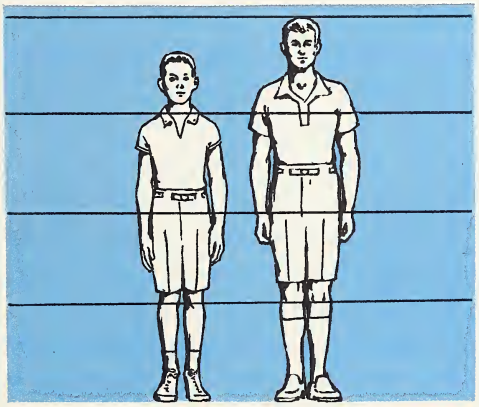
Look at the diagram on the next page which compares a boy's body with an adult's. About how much of the boy's height is taken up by head and neck? How does this compare with the body of an adult? How much of the boy's height is taken up by legs? How does this compare with the body of an adult? From this evidence, what would you say about how someone's body changes as he grows up?

Comparison of Heights

How do the heights of different parts of your body compare with the heights of the same parts of your parents' bodies?

Have one of your parents measure your total height. Then have him measure the length of your neck and head from your shoulders up. Next have him measure the length of your legs from your hips down. Record your various measurements in inches. Do a **scale drawing** showing all the measurements. You can make such a drawing by letting ⅛ of an inch represent one inch of your actual height. The scale drawing of yourself will be only ⅛ as tall as you are.

How do the heights of different parts of this boy's body compare with his father's body?



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You can take your parents' measurements in the same way. After you have a record of the measurements, make scale drawings of your parents' heights. Now compare the scale drawing of yourself with those of your parents. How do your neck, head, and leg measurements compare with those of your parents?

Rates of Growth

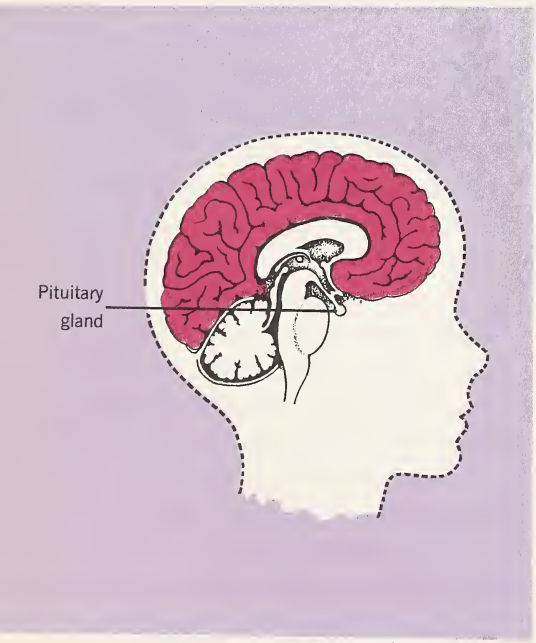
Although most people grow until they are about twenty-five years old, their rate of growth varies from year to year. Children grow most rapidly during their first two years. After this period, the growth rate of children slows down. Girls begin to grow quickly again when they are between twelve and fourteen years of age. At this time, their rate of growth increases. They may grow as much as three or four inches each year during this two-year period. We call such rapid growth a growth spurt.

The growth spurt for boys does not generally occur until they are about fourteen years old. Usually girls have their growth spurt two years earlier than boys. This explains why twelve- and thirteen-year-old girls are often taller than boys of the same age. After sixteen years of age, boys have caught up and generally grow taller than girls.

Some boys and girls grow faster than others. They often stop growing early, and the slow growers may finally be taller than the fast growers.

As you grow up, you can expect another change. Your body will change its shape from that of a child to that of an adult. Usually girls begin to change earlier than boys.

Everyone has his own pattern for how much he will grow and when he will grow. You, too, have your own pattern, and it may be quite different from that of your friends.



Growth Regulators

Although people stop growing when they are about twenty-five years old, some animals and plants continue to grow for as long as they live. Can you name such animals or plants and tell how they are able to continue growing? Why do people stop growing? This is a question that scientists have not been able to answer. However, scientists do know many things about growth.

Look at the picture on this page. There is a gland located in the head just beneath the brain. This gland is called the **pituitary gland** (pih-TOO-uh-tehr-ee). It produces **hormones** (HOR-mohnz). A hormone is a chemical that causes certain things to happen in the body. A hormone travels in the blood from certain glands to parts of the body. One of the hormones produced by the pituitary gland regulates the rate at which the bones grow. Have you ever wondered why some people grow to be giants? While giants are growing, their pituitary glands produce too much hormone. This causes their bones to grow larger than normal. Sometimes the opposite thing happens. When the pituitary gland does not produce enough hormone, the bones do not grow properly. When this happens, the person is a dwarf.

Full-grown animals and people need a variety of materials to work and play and stay alive. They need these materials so that the systems of their bodies can grow, develop, and work properly.

In the next unit, you will learn more about your body. You will learn about the many systems that enable *you* to breathe, eat, move, get rid of wastes, and react to your surroundings.

Using What You Have Learned

1. Ask your school nurse for figures showing the heights and weights of children of different body builds at various ages. Make a growth graph for each build—narrow, medium, and broad.

If you cannot get such figures from the nurse, make a survey of your classmates and then make a growth graph for each classmate.

2. Plants also have growth hormones. The best known of these hormones are the **auxins** (AWK-sinz). You may be able to get an auxin at a nursery or a florist shop. Cut some branches off a plant and apply the auxin as directed on the package label. What happens? Keep a record of what you do and of what happens.

3. Look at photographs of your parents. Your parents have grown and developed through the years. Look at photographs of yourself and compare them with photographs of your parents at various ages. How is your growth pattern the same as those of your parents? Do you see any differences? Can you account for these differences?

4. Find out about the hormones in your body. How would you go about finding good sources?

After you learn about hormones, make a chart to show what each hormone in your body does.

WHAT YOU KNOW ABOUT

Growth and Development

What You Have Learned

All living things have an orderly pattern of development. **Embryologists** study the early development of living things.

A chicken has an orderly pattern of development. The egg cell is fertilized by one of a rooster's **sperm cells.** Three cell layers form as the fertilized egg cell develops: the **ectoderm,** the **endoderm,** and the **mesoderm.** The time in which a fertilized egg cell develops is called the **incubation period.**

In flowering plants, **fertilization** takes place after the nuclei of the **pollen grain cells** join with the nuclei of the **ovule cells.** As the plant seed forms, it develops three main parts: a seed coat, stored food, and an undeveloped plant. Development of an embryo plant is called **germination.**

For a single fertilized egg cell to grow and develop into a many-celled, complex organism, it requires certain materials. Food supplies these materials. A chick embryo gets its food from the egg **yolk.** The embryo plant in a seed gets its food from materials stored in the seed. The human embryo gets its food from its mother's body.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

embryo	hormone	ovule
embryologist	larva	pistil
embryology	ovary	pituitary gland
germination	oviduct	stamen

Find the Order

Write in your notebook the correct order of the stages in the life of a butterfly.

larva adult egg pupa

Can You Tell?

The picture shows the parts of a flower. Tell what each part is.

1. What does the pistil contain?
2. What does the stamen contain?

Complete the Sentence

Write the numbers 1 to 5 in your notebook. Next to each number, write the word or words that best fit the space in each sentence.

1. The time it takes for a complete chick to develop from a fertilized egg cell is called the ___?___ ___?___ .
2. The science of the early development of living things is called ___?___ .
3. The development of a plant from a seed is called ___?___ .
4. The wormlike animal stage of an insect is called the ___?___ .
5. A gland that produces hormones, found just beneath the brain of a human being, is the ___?___ .

YOU CAN LEARN MORE ABOUT

Growth and Development

G
E
R
M
I
N
A
T
I
O
N

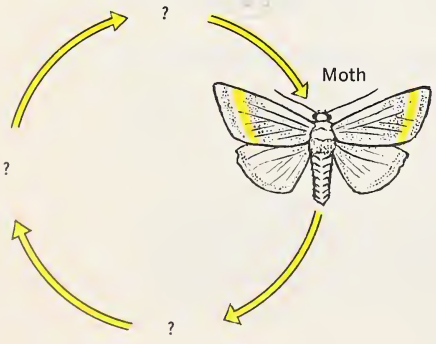
What Are the Words?

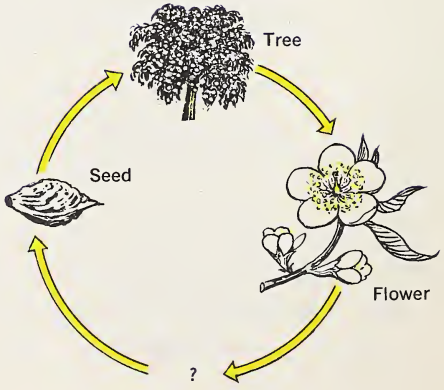
Each letter in this word is also a letter in a science word, or words, that you have learned in this unit. Find a word for each letter without using the same word more than once.

Tell a Life Story

Make a circle of arrows as shown in the picture on the left. Draw pictures in the spaces left by the arrows to tell the life story of a moth.

In the circle of arrows on the right we have started the life story of a peach tree. What is missing?





You Can Visit

A botanical garden has many different kinds of plants. How does a botanical garden provide the proper environmental conditions for each? How many different kinds of environments can you find?

Notice also how the hothouses are built. Is there a heating system in the hothouses? If not, why is it so warm? Are the plants in some of the hothouses moist?

Many botanical gardens show films or have talks on Saturdays. Others have special summer programs for boys and girls your age. Find out if the botanical garden you visit has such programs.

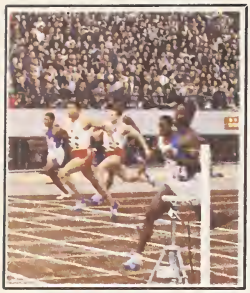
You Can Read

1. *How Things Grow,* by Herbert S. Zim. A good introduction to human growth and development.
2. *Why You Are You,* by Amram Scheinfeld. Why you look, think, and act as you do.
3. *The Man Who Found Out Why: The Story of Gregor Mendel,* by Gary Webster. Mendel's experiments as a pioneer in the study of genetics.
4. *Who Do You Think You Are? The Story of Heredity,* by Marguerite R. Lerner. Information on DNA, genes, the beginning of human life, and the development of the embryo.

4

Systems of the Body

Keeping Alive
Adjusting to Changes
Doing Things Without Thinking



Man has invented machines that do amazing jobs. Nuclear-powered submarines travel the world without surfacing even once! Electronic "brains" can solve more arithmetic problems in two minutes than your whole class can do in two months. Yet no machine is as amazing as the human body.

Keeping Alive

Think of the activities going on right now inside your body. Your digestive system is working to change the food you ate so your body can use it. Your heart is pumping blood to all parts of your body. Your muscles are keeping you in an upright position. You are also breathing, getting rid of wastes, using hundreds of muscles, and doing much more. And while all these activities are going on you are also learning about science as you read this book.

Jacques Piccard went to a depth of 35,800 feet in the bathyscaphe Trieste, built by his father, Auguste Piccard. Colonel John Stapp rode in a rocket that went over 630 miles an hour. Pilot Joseph Walker traveled to a height of 354,200 feet in the X-15 test plane. Twenty years ago, men could not have done these things. They could not because scientists did not know enough about how man's body works.

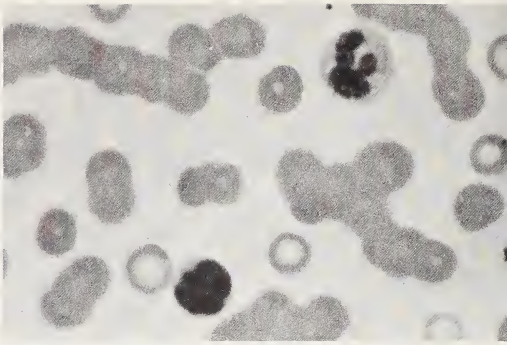
How long can man go without food? How long can man go without sleep? Astronaut Alan Shepard is undergoing tests to help find out.

The purpose of this test is to find out how the body withstands increases in heat.

These men are floating in air. They are finding out how weightlessness affects the body. Why do you think they want to know?

All these experiments and hundreds, even thousands, more give scientists information about the workings of the human body. Still, there is much that scientists want to know.

All forms of life must carry on certain activities to stay alive. Lower forms of life, such as the ameba, carry on the activities of getting food and oxygen and getting rid of wastes in very simple ways. The one-celled animal has only one cell which carries out all these activities. Man has several complicated systems, each with a certain job to do. In this unit, you will find out about the various systems of the human body and how they work to maintain life.



Blood as seen under a microscope. Can you identify the white blood cells?

Blood—Your Body's Lifeline

There are many different kinds of transportation systems in the world. There are trains, buses, automobiles, airplanes, and even, today, rockets. But the most wonderful transportation system is right in your own body. It is the bloodstream.

The bloodstream carries everything the cells need to maintain life. It is in the cell that the work of maintaining life goes on.

Cells use food and oxygen. They need to get rid of wastes. How do cells get food and how do they get rid of wastes? Every cell in the body is very close to tiny blood vessels. These blood vessels bring food and oxygen to the cells and carry away waste materials. Blood vessels do not actually touch the cells, but fluids from the blood seep into the spaces around the cells. Each cell is bathed in these fluids and absorbs food from them.

As the blood **circulates** (SER-kyoo-layts), or moves, through the body, it picks up products from one part of the body and carries them to another. Oxygen, for example, is carried in the blood from the lungs to every cell in the body. Hormones are carried in the bloodstream from glands to certain cells. The blood carries food from the intestines to cells throughout the body. Each cell absorbs, from the bloodstream, what it needs. Now do you see why the bloodstream is sometimes called the "river of life"?

Simple animals like sponges do not have a bloodstream. However, they still need to have materials circulated to all

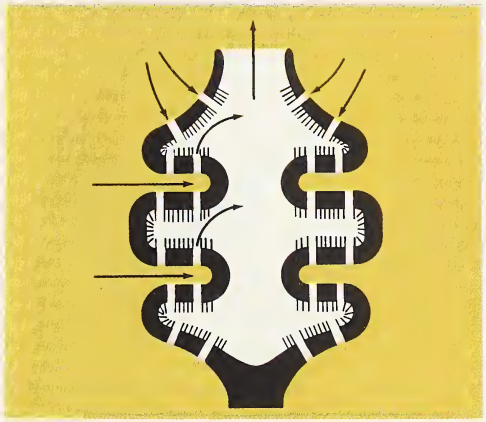
parts of the body. The materials they need to circulate are in the form of molecules. Molecules are always in motion. They move in all directions until they are spread evenly throughout the space available. If there are many molecules in one spot, then some molecules will move to where there are not so many. The movement of molecules from a place where there are many to a place where there are fewer is called **diffusion** (dih-FYOO-zhun). Sponges take in water through their pores and filter out bits of food in the water. Then, through diffusion, the food is circulated.

Try this to see how diffusion takes place. You will need a glass of water and some ink (India ink is easiest to see). Add a drop of the ink to the water. Describe the way in which the ink moves through the water. Use a magnifying glass for a closer look.

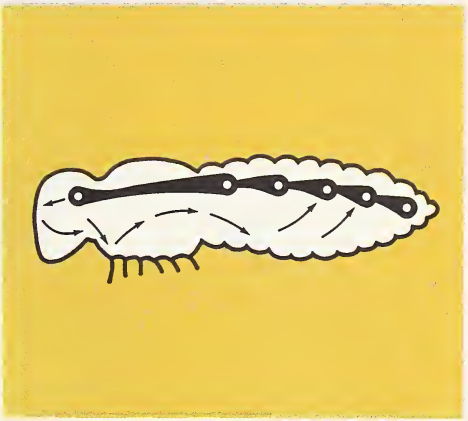
Some simple animals have a circulatory system, but one that is simpler than the human system. An insect such as a mosquito has a blood system. The system is called an "open" one. The blood vessels open directly to the body cavity, where the heart and other organs are bathed in blood.

All animals with backbones have a more complicated circulatory system. It is made up of a heart and vessels of various sizes that carry the blood.

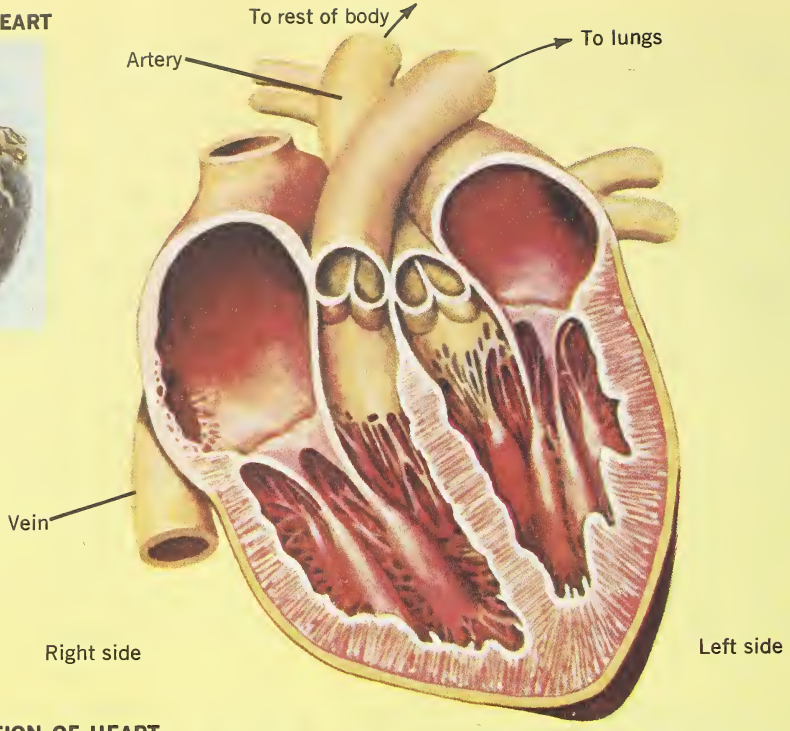
All the life activities of a sponge depend on a continuous flow of water through its porous body. This flow of water is the sponge's only means of getting food and oxygen and getting rid of wastes.



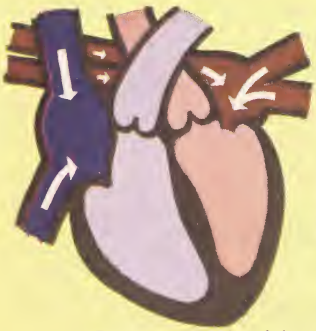
An insect, such as a grasshopper, has only one blood vessel, with openings through which blood enters. From one end of the vessel, blood drains into the head and body, carrying food and picking up wastes.



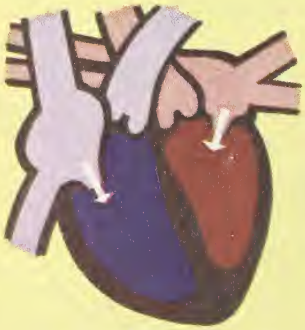
THE HUMAN HEART



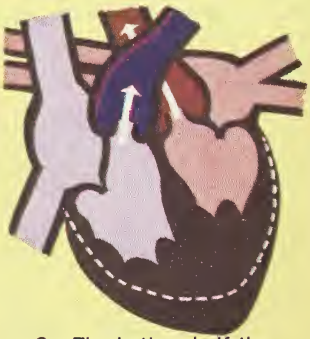
PUMPING ACTION OF HEART



1. Blood enters the right side of the heart from all parts of the body. At the same time, blood from the lungs enters the left side of the heart.



2. Blood from the right side flows into the bottom half of the right side. Blood from the left side flows into the bottom half of the left side.



3. The bottom half then squeezes, pumping the blood from the right side to the lungs and the blood from the left side to the rest of the body.

Your bloodstream is like a river with many, many branches. But while rivers flow only downhill, your blood flows up as well as down. A pump is needed to keep pushing the blood through your body. That pump is the heart. No pump made by man can compare with your heart. Your heart pumps blood for as long as you live.

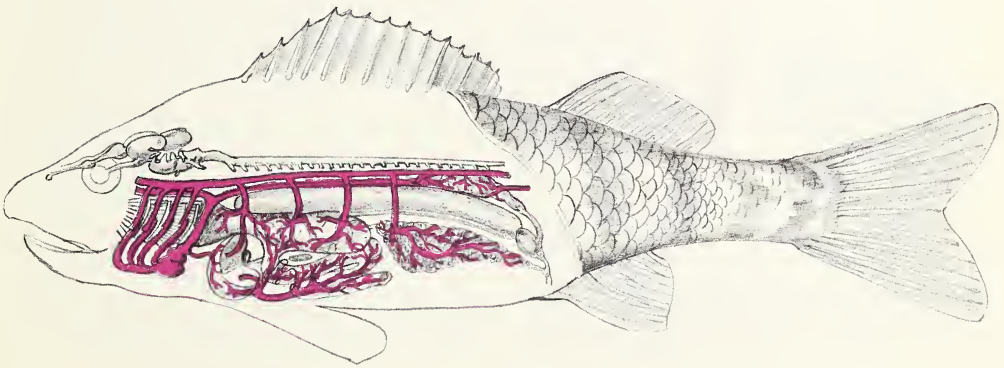
The Heart

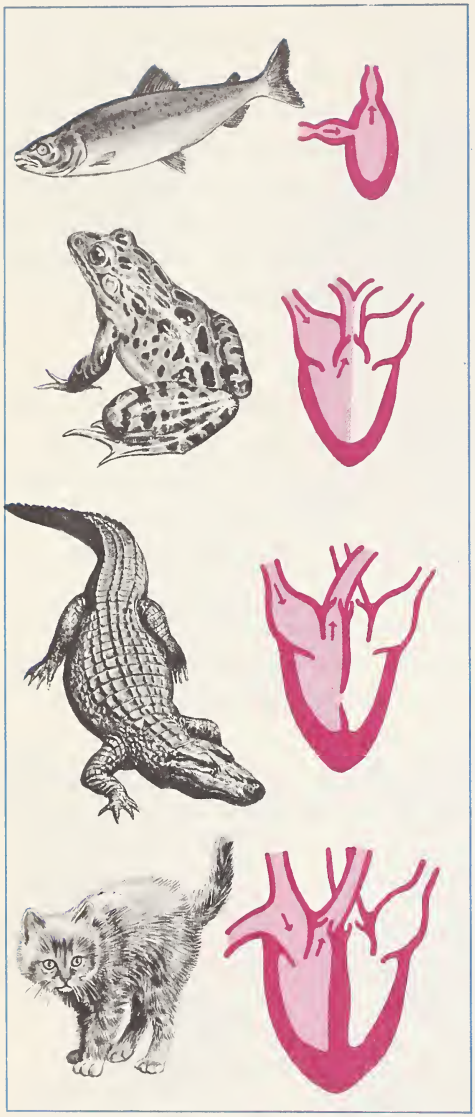
Your heart is really a double pump. The right side is one pump, and the left side is the other. The right side pumps blood to the lungs. The left side pumps blood to the rest of the body.

Most animals have a heart that pumps blood. Even the ant has a heart! However, its heart is only a long, muscular tube. From this tube, blood moves forward in waves as the muscles of the heart first contract and then relax. Fill a long, narrow hose with a liquid, such as water. Then use the muscles of your hand to squeeze the hose. You will see how the ant's heart muscles move blood along. The muscles must relax before the next big squeeze, or contraction. The movement along the tube is a wave-like contraction and relaxation.

The fish has a more complicated heart than the ant has, but the fish's heart still does not have two sides as your heart does. The fish's heart sends blood through a large blood vessel to the gills. There the blood picks up oxygen, and then the blood goes to vessels that carry it to all parts of the body. The blood is never pumped directly from the heart into the body of the fish.

The heart of a fish is found near its throat. Red lines shows the circulatory system in a fish. How does circulation in a fish compare with that in an insect?



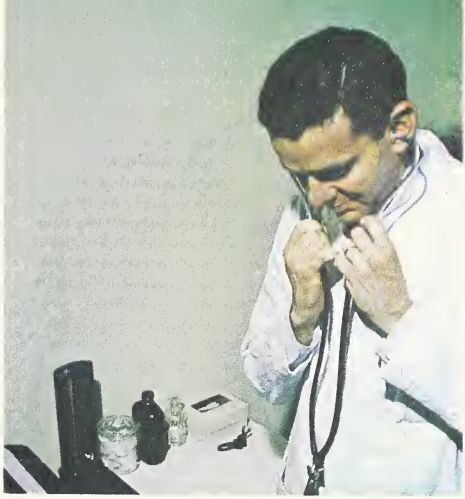


How do the hearts of these four classes of vertebrates differ? Why isn't a bird's heart shown? What kind of heart do birds have?

It is only in creatures such as birds and mammals that we find the heart divided into two separate halves. One side has blood with oxygen in it. The other side has blood that must be pumped to the lungs to pick up oxygen. There is no mixing of the two kinds of blood in this type of heart.

Look at the picture of the human heart. It is about the size of your fist. Do you see the tubes that lead away from it? They are called blood vessels. There are three kinds of blood vessels. The **arteries** (AHR-ter-eez) carry blood away from the heart. The arteries branch into **capillaries** (KAP'l-ehr-eez). The capillaries are the thinnest blood vessels in the body. They are only one cell thick. Can you tell why they are so thin? How would you find out? The capillaries must be able to carry the blood to every body cell. The **veins** (vaynz) carry blood back to the heart from the capillaries. You can see some veins in your hands and arms. They look bluish.

You can feel the pumping action of the heart. There are some places in the body where an artery is close to the skin. One such place is the inside of your wrist. Another is your neck. You can feel the heartbeat in these arteries. The beat in an artery is called a **pulse.**



Doctors use the artery in the wrist to count your pulse. You can do the same. Hold the first two fingers of your right hand lightly against the inside of your left wrist in line with the left thumb. Do you feel a beating? Use a stop watch or a watch with a second hand to count the number of beats in one minute. How fast does your heart beat? Now stand up straight and touch the floor ten times, bending from the waist each time. Count the number of beats again. How does the second count compare with the first?

Why does exercise cause your heart to beat faster? The muscles in your legs and arms and other parts of your body have been relaxed. Suddenly you exercise by moving up and down to touch the floor. Your muscles must now work hard. These muscles need more food and oxygen quickly. The blood brings the food and oxygen to the muscles. The blood supply must be increased to carry the extra load. The heart speeds up its beating from about 100 beats per minute to 120 beats or more. After you have finished exercising, the muscles no longer need a big blood supply. The heart goes back to its normal beat. This all happens without your having to think about it. It happens automatically. Imagine if you had to remind your heart to speed up or slow down all the time!

When you go to the doctor's office, he usually listens to your heartbeat. He does this by using a **stethoscope** (STETH-uh-skohp). What does the doctor hear?

If your heart is normal, he hears rhythmic clicks and thumps. If there is something wrong, he may hear irregular clicks and thumps. If there is a leak, he will probably hear a swishing sound. The normal heart sounds something like "lub-dub—lub-dub—lub-dub."

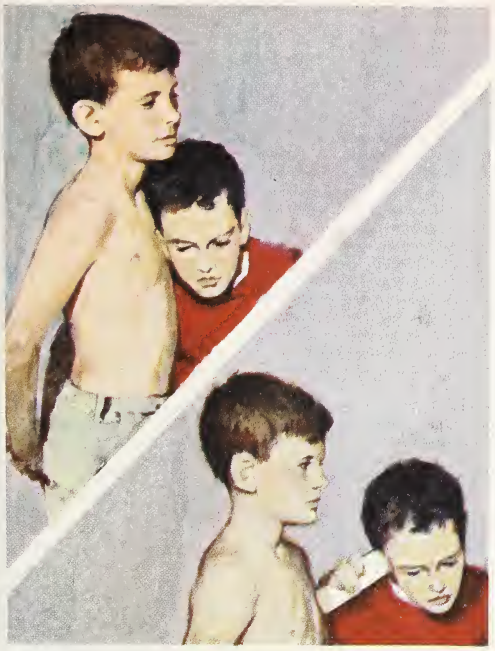
The stethoscope is really a very simple instrument. It is merely a flexible tube which transmits sounds. Actually, you can hear these sounds by placing your ear snugly against the skin of another person's chest.

In 1819, a young physician named Théophile Laënnec (lay-NEK) wanted to listen to the heartbeat of a sick girl. She was very heavy, and a thick layer of fat blanketed the sounds of her heart. That afternoon, as Dr. Laënnec was strolling through a park, he came upon some boys bending over a long wooden beam. They had their ears tightly pressed against one end of it. At the other end, another boy was tapping lightly on the beam. Laënnec saw the solution to his problem. When he returned to the hospital, he rolled some papers into a tube. He placed one end of the tube to the girl's chest and then placed his ear at the other end of the tube. Läennec heard the girl's heartbeat more clearly and crisply than he had before.

Day after day, Dr. Laënnec passed through the wards of the hospital with his paper tube tied with strings, listening to hearts and carefully making notes. Because paper tubes did not last long, Laënnec made a tube of wood. He gave the instrument a Greek name, stethoscope, which means "chest examiner." As time went by, Laënnec's stethoscope was improved. Today, the stethoscope is as much a part of the doctor as the bag in which he carries his instruments.

You can make a stethoscope by rolling up a piece of paper and slipping a

Théophile Laënnec invented the stethoscope.



rubber band around it. Put one end of the tube to another pupil's chest and the other end to your ear, as in the picture. What do you hear? Sounds come through a doctor's stethoscope more clearly. With a glass Y-shaped tube, rubber tubing, and a funnel, you can make a stethoscope.

Digesting Your Food

Late in the nineteenth century, scientists knew very little about what happens in the body of a living person. Operations were not common, because they were nearly always fatal. Direct observations of what goes on inside the body were rare until quite recently.

In 1822 a strange thing happened. A trapper named Alexis St. Martin was accidentally shot in his left side. He was brought to William Beaumont, a doctor in the United States Army. The doctor patched the wound as best he could, but it never closed properly. Instead, the wall of the stomach healed by growing to the skin and muscles of the body wall. This left a hole in the left side of St. Martin's body that led to the inside of his stomach. The hole provided Dr. Beaumont with a "window" to observe and study the workings of the stomach. St. Martin co-operated with Dr. Beaumont, and the doctor was able to make many observations over a period of eleven years.

Dr. Beaumont saw that the stomach gives off a fluid. He put some of this fluid on meat and found that the meat was partly digested. He also saw the stomach move and churn when food was in it. He did many experiments and learned much about the stomach. Dr. Beaumont's experiments led the way for other scientists to make many more discoveries about how the stomach digests food. What you will read here about the digestive system is the result of the

EXPERIMENTS, &c.

FIRST SERIES

Experiment 1.

August 1, 1825. At 12 o'clock, M., I introduced through the perforation, into the stomach, the following articles of diet, suspended by a silk string, and fastened at proper distances, so as to pass in without pain—viz. :—a piece of high seasoned *a la mode beef*; a piece of *raw, salted, fat pork*; a piece of *raw, salted, lean beef*; a piece of *boiled, salted beef*; a piece of *stale bread*; and a bunch of *raw, sliced cabbage*; each piece weighing about two drachms; the lad continuing his usual employment about the house.

At 1 o'clock, P. M., withdrew and examined them —found the *cabbage* and *bread* about half digested: the pieces of *meat* unchanged. Returned them into the stomach.

At 2 o'clock, P. M., withdrew them again—found the *cabbage, bread, pork*, and *boiled beef*, all cleanly digested,† and gone from the string; the other pieces of

Dr. William Beaumont studied digestion by observing the process through an opening in Alexis St. Martin's side. On the right is a page from Dr. Beaumont's book published in 1833 reporting many experiments he was able to make.

work of hundreds of scientists over many years. But there is still much to be learned.

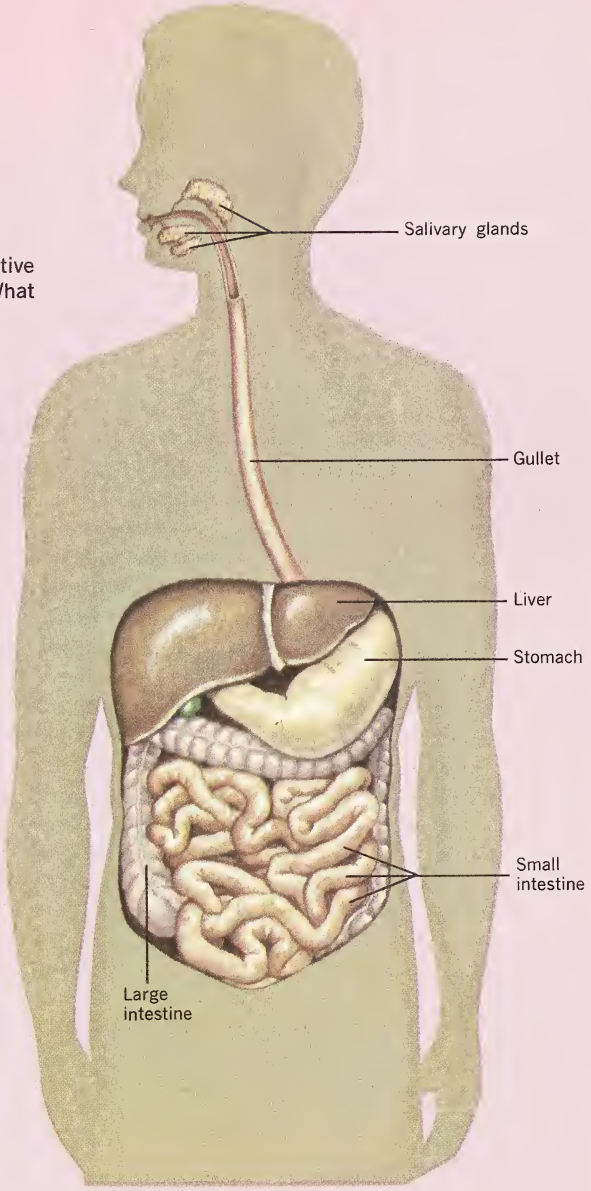
Look at the X-ray picture of your **digestive system** (dih-JESS-tiv). When you swallow some food, it goes down the **gullet** (GUL-it) into the **stomach** (STUM-ik) and then into the **small intestine** (in-TESS-tin). Whatever is not digested leaves the body by way of the **large intestine.** You may think that the food makes a rather quick trip through your body. But actually scientists have learned that the process of digesting food and getting rid of wastes takes about twenty-four hours.

What has to be done to the food so that your body can use it? You know that your body is made up of billions of cells. All of these cells need food to stay alive. How do all these cells get food? Blood carries food to the cells. But it cannot carry a piece of hamburger or a piece of potato or celery. Can you tell why? All of the solid foods that you eat have to be changed. Changing them so that they can be carried to your cells is the work of the digestive system.

The work of breaking down your food begins in your mouth. As you chew, your food is mixed with **saliva** (suh-LY-vuh). In your mouth are tubes

THE DIGESTIVE SYSTEM

The X-ray picture shows part of your digestive system. Look at the diagram at the right. What can you now identify on the X-ray picture?



through which the saliva flows. Saliva comes from **salivary glands** (SAL-uh-vehr-ee). Did you ever smell a pie just out of the oven or bacon sizzling on a stove? Did your mouth water? This watering is called salivating.

After chewing carefully, you swallow a small ball of food, which is moved along through the gullet to your stomach. Here the food stays for some time while it is churned. Juices from the stomach are mixed with the food. These juices help break down the food. What do you think the churning does to the food?

After a while, the food is moved on to your small intestine. Here more juices are mixed with the food. It is in the small intestine that digestion is completed.

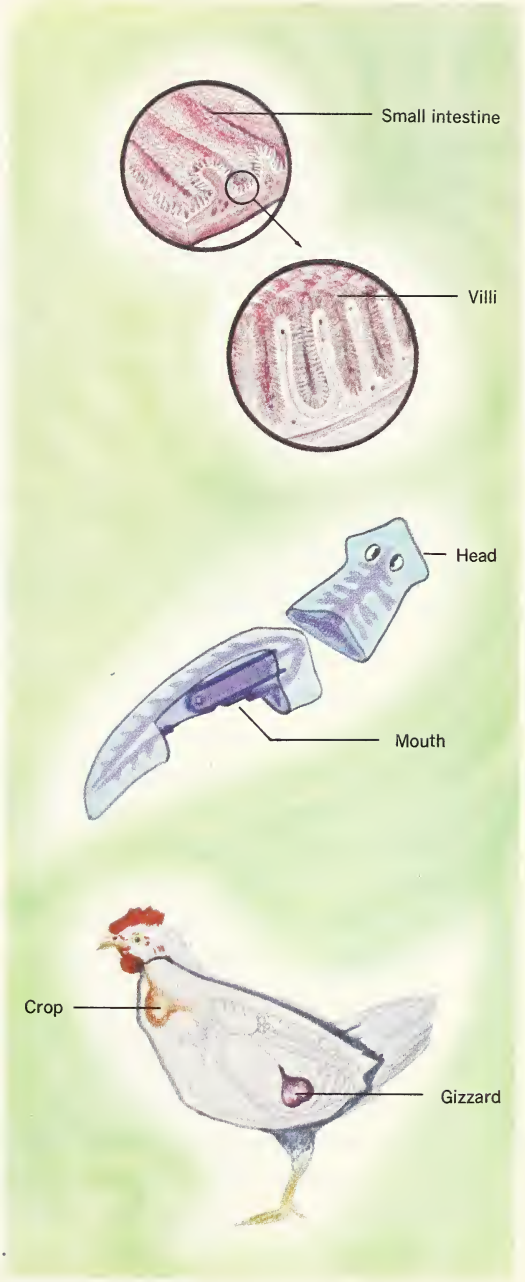
Suppose you ate celery and potatoes with your dinner. There are some parts of the celery and potatoes that you cannot digest. These parts are the cell walls of celery and potato. The cell walls of plants are made of cellulose. Your body cannot break down the cellulose. This undigested part of the food passes into your large intestine. The water in the food passes through the large-intestine wall into your blood. Other undigested food collects in the lower part of the large intestine and finally passes out of the body through the **anus** (AY-nuss). Doctors say it is important to get rid of food wastes regularly—once a day or once every two days. Sometimes people cannot get rid of wastes regularly. This condition is called **constipation** (kon-stuh-PAY-shun). Many people can correct this condition by eating more foods, such as celery, that contain **roughage** (RUF-ij). Roughage cannot be digested. As the muscles in the large intestine push it along, wastes are carried with the roughage out of the body. If constipation continues for a while, see your doctor.

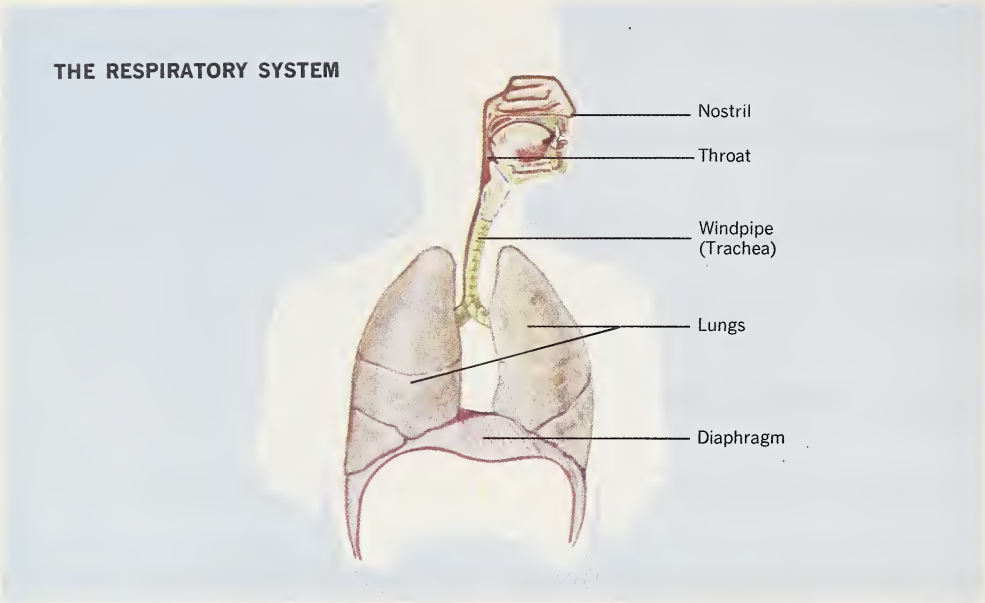
Look again at the diagram shown on page 89. The small intestine looks like a jumbled ball of rope. To get an idea of how long the small intestine is, unravel a piece of cord or rope 20 feet long while another pupil holds one end. Start at the front of the classroom and walk toward the back as you unravel the cord. Now do you see how long 20 feet is? In the adult, the small intestine is 20 feet long, and the large intestine is 4 to 5 feet long. You may wonder why the small intestine is not called the large intestine. The small intestine gets its name because it is not as wide around as the large intestine. In the illustration, you can see the difference in width between the large and small intestine.

Remember that digestion is completed in the small intestine. That means that when the food leaves the small intestine it goes to the cells. How does the food get to the cells? Look at the lining of the small intestine in the picture at the right. See all the little "fingers." They are called **villi** (VIL-eye). Inside each one are blood capillaries. Digested food passes into the bloodstream by means of these capillaries. The blood carries food to the cells.

Some simple animals digest food in a very uncomplicated way. In a planarian (pluh-NAIR-ee-un), food passes from the mouth directly to an opening inside the body. Nearby cells release chemicals into the opening. These chemicals prepare the food for use by the planarian's body. Food that is not digested leaves the body the same way it came in—through the mouth.

Chickens and other birds have a more complicated digestive system than the planarian. Have you ever examined a chicken that has not been cleaned? Perhaps you have seen the **crop,** where food is stored. You may also have seen the **gizzard,** where food is ground against small stones to prepare it for digestion. Study the diagram. How is the digestive system of the chicken like that of mammals? How is it different?





Trace the path of air into and out of the body, using the diagram. What role does the diaphragm play in breathing? What keeps the food you eat from entering the windpipe when you swallow?

What Happens When You Breathe

You need more than food to stay alive. You need oxygen.

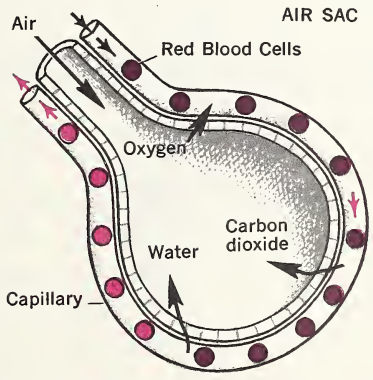
How do the cells get oxygen? Again, the bloodstream serves as the means of transportation. It carries oxygen to every cell. Now you will find out how oxygen gets into the bloodstream. This work is carried on by the **respiratory system** (rih-SPYR-uh-tor-ee).

If you were able to look inside your body, you would see a **windpipe** with two branches, each going to one of your lungs. You would also see a **diaphragm** (DY-uh-fram). Look at these parts in the picture.

Every time you take a breath, your diaphragm goes down. This action pumps air into your lungs. When you breathe out, the diaphragm goes up and the air in your lungs is pushed up through your windpipe and then out through your nose. Your diaphragm goes up and down over 20,000 times a day, about 16 times every minute, without your having to think about it.

Look again at the picture showing the windpipe. See how it branches in two. Each branch goes into a lung. Inside each lung, each branch branches again and again and again into many, many smaller branches. At the ends of the smallest branches are air sacs that look like tiny balloons.

The lungs contain millions of these air sacs. The smallest branches pipe air into and out of the air sacs. The air sacs are only one cell thick. They are so very small that you need a microscope to see them. Around each air sac are capillaries carrying blood. Now you can tell how oxygen gets into the bloodstream and how the bloodstream delivers carbon dioxide, a waste product, to the lungs.



Oxygen passes out of each air sac into the capillaries that surround it. Carbon dioxide and water pass from the capillaries into the sac and are removed when you breathe out.

Getting Rid of Wastes

Things that you do not need or want, you throw away. Your mother throws the bones of chicken, meats, and fishes into the garbage pail. The food the family left from breakfast, lunch, and dinner may also be thrown away. Every day the garbage pail is filled and emptied into an incinerator or the garbage is put outside to be collected. What would it be like if you did not get rid of these wastes? What if there were no way of getting rid of the sewage, the dirt, and the rubbish of your city? Your city would not be a very healthful place.

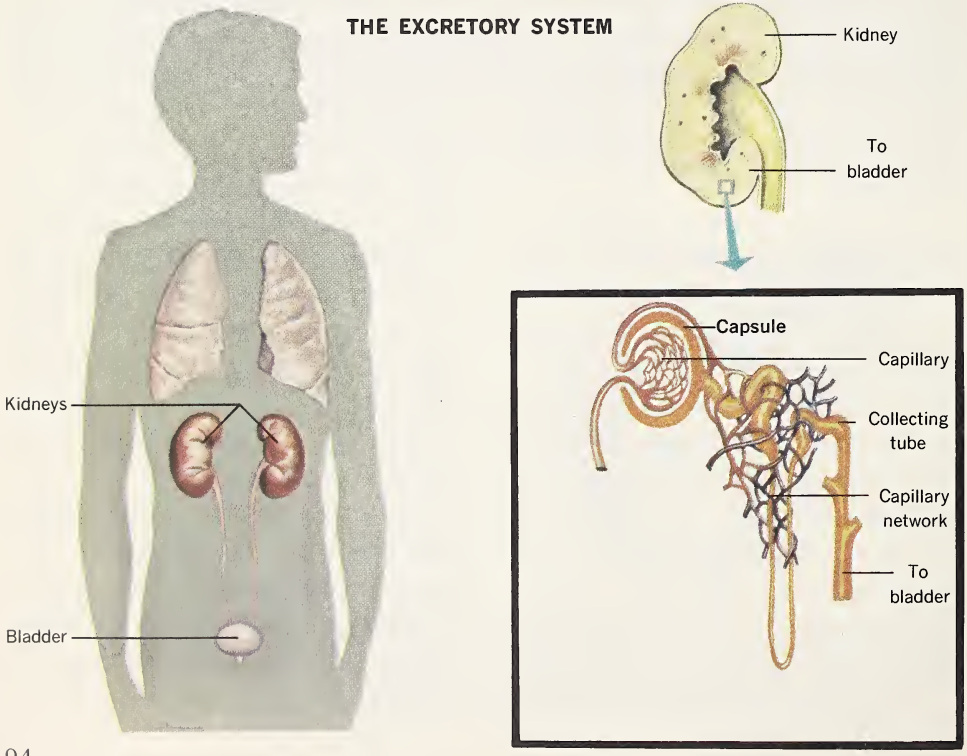
Your body would not be very healthy if it did not get rid of wastes all the time. If your body did not get rid of them, these wastes would poison your cells. Certain diseases occur because the body cannot get rid of wastes. The wastes gather in the tissues. They affect the normal working of the body. Your body gets rid of wastes by way of the **excretory system** (EKS-krih-tor-ee). Again, your bloodstream serves as the means of transportation.

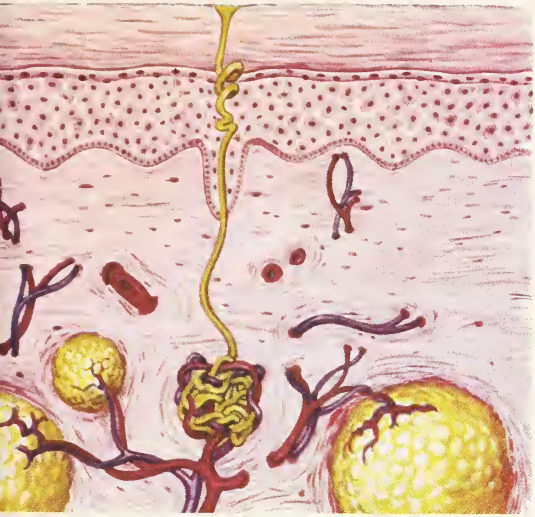
You already know two ways in which your body gets rid of wastes. Your lungs give off carbon dioxide when you breathe out. Roughage and bacteria wastes from your intestine leave the body by way of the anus.

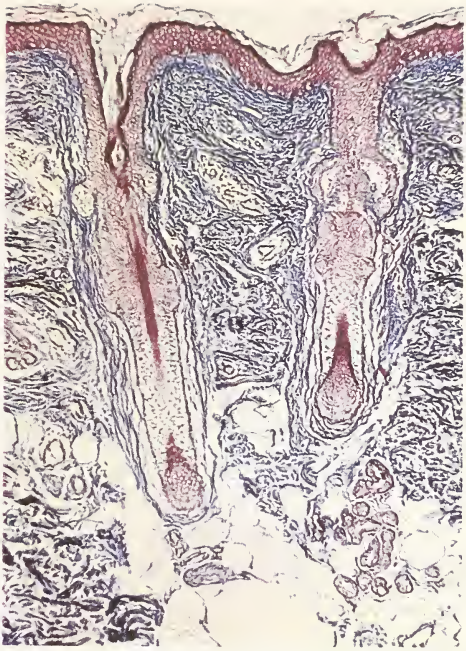
Wastes from your cells enter the bloodstream and are carried to the **kidneys** (KID-neez). Look at the picture to see where your kidneys are located. Notice that there are two kidneys. Each kidney is attached to the **bladder** (BLAD-er) by a long tube. Inside each kidney are many hollow tubes that curl around and around. Each tube ends in a cup. Inside the cups are masses of capillaries. The cups with their tubes and capillaries act as little **filters.** A filter is like a strainer. It lets certain things through but not others.

There are about two million filters in the kidneys. Every three minutes the whole five to six quarts of blood in your body pass through one of the kidneys.

Within the kidneys are about two million "filters." Each filter is a very small capsule leading into a coiled collecting tube. Water and other wastes pass out of the capillaries into the capsule. Some water and dissolved foods pass back into the blood as the fluid flows through the coiled tube. The rest empties into the bladder.







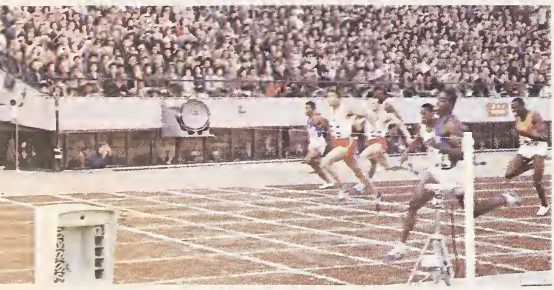
These are the pores in the skin. Each pore is the opening of a sweat gland. A sweat gland is a tiny tube coiled up into a ball surrounded by capillaries. How do water and other wastes get to the surface of the skin?

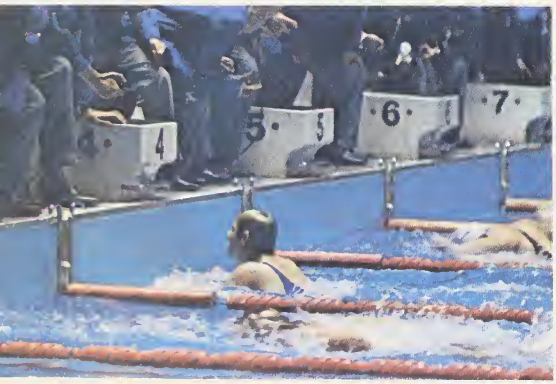
The kidneys filter your blood. What is left is called **urine** (YOOR-in). Urine passes down into the long tubes leading to the bladder. It stays there until you **urinate.**

Your kidneys keep the amount of salt in your blood about the same all the time. They control the amounts of sugar and water, also. Your kidneys help you to stay alive and healthy.

Your skin also helps you get rid of wastes. When you run or jump, you sweat. You also sweat on very hot days. But did you know that you are always sweating a little bit? Right now, as you read this book, you are sweating, or **perspiring** (per-SPYR-ing). Sweat, or **perspiration,** is mostly water with some salts dissolved in it. This is why sweat has a salty taste. Where does sweat come from?

Sweat glands are located in the underlayer (dermis) of your skin. These glands remove water and salts from the blood and pour them in the form of sweat through tiny openings in your skin. You can see these openings if you look with a magnifying glass.





Your Muscles and Bones

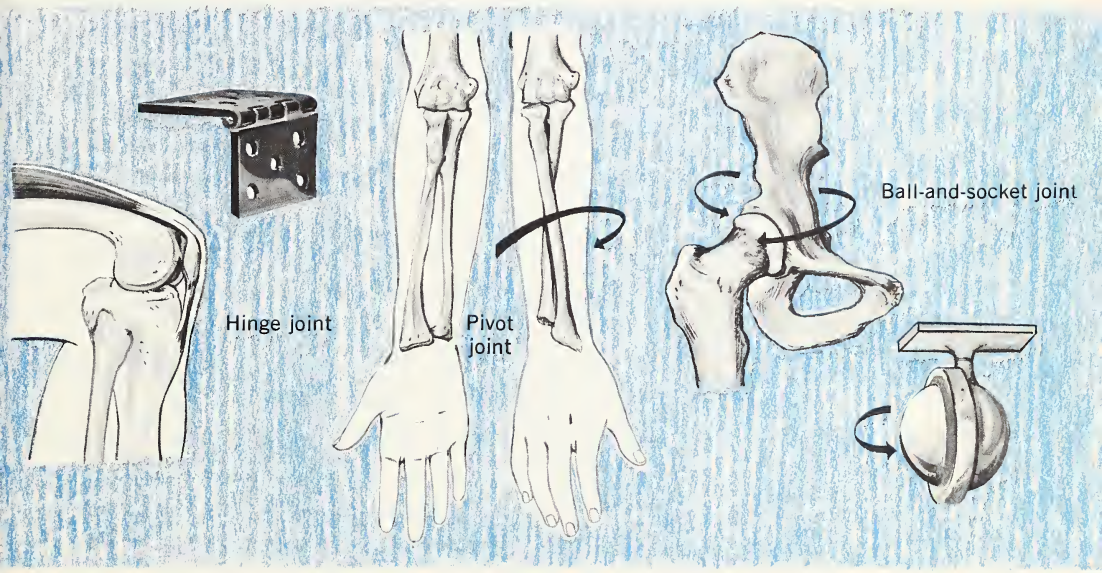
The people in the pictures at the left could not have done these things without **bones** and **muscles.** Every move that you make requires the smooth working of bones and muscles. There are over 800 muscles and 206 bones in your body.

Muscles do work only when they get shorter. When a muscle gets shorter, it is said to contract. When a muscle contracts, it pulls or turns some part of the body. You can feel this happen. Place one hand around the upper part of your other arm. Bend that arm. Do you feel a bulge? The muscle is getting shorter. Straighten your arm. The muscle on the outside of your arm contracts. One muscle bends your arm, and another one straightens it. Muscles can do work only when they contract.

Most of the muscles you use in moving are fastened to bones. Your bones make up the framework that supports your body. Some of your bones also protect vital organs, such as the brain, heart, and lungs.

You can turn your head from side to side. You can bend down to touch your toes. You can bring your knee up to your chest. You can move in these and other ways because your skeleton is **jointed** (JOYNT-id).

Which muscles are doing work in each of these pictures? How can you tell?



What is a joint? Have you ever seen a puppet dance and bow? When its strings are pulled, a puppet can move in certain ways because it is jointed. It has joints at its elbows and knees, and its neck, and at its wrists and ankles. The joint is where the end of one piece of wood meets the end of another piece.

Your joints are places where the end of one bone meets the end of one or more other bones. Look at the picture on page 97. The elbow joint is where the end of the bone of your upper arm meets the ends of the two bones in your forearm. You have joints in your hands, legs, feet, backbone, and lower jaw. You have four kinds of joints: hinge joints, pivot joints, gliding joints, and ball-and-socket joints. The picture shows how three kinds of joints work.

Using What You Have Learned

1. As you grow up, your heart beats more slowly. A newborn baby's heart beats about 140 times a minute. By the time he is three years old, it has slowed down to about 120 beats a minute. Between the ages of five and twelve, it beats about 100 times a minute. Between thirteen and twenty-one, it beats about 90 times a minute. After twenty-one, it beats about 75 times a minute.

Knowing this, would you expect the rate of your heartbeat to be much different from that of your parents'? Each member of the class might find out these rates and compare his findings with those of his classmates.

2. Here are the heartbeats of several adult mammals:

Elephant: 25 beats a minute
Horse: 50 beats a minute
Dog: 100 beats a minute
Rabbit: 150 beats a minute

From this evidence, what could you hypothesize about the sizes of mammals and the rates at which their hearts beat?

3. Does your heart beat faster:
when you are standing up or lying down?
when you are in a warm room or outside where it is cold?
before or after you eat a meal?

Plan an experiment to compare your results with those of other members of your class.

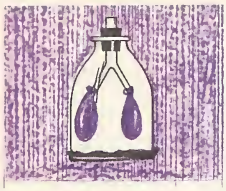
4. Put a teaspoon of cornstarch in one glass of water. Put a teaspoon of sugar in another glass of water. Stir each with a spoon. Why is the starch water cloudy and the sugar water clear? Has the starch dissolved? Let the glasses stand for one day. What happens to the starch? How does this help to explain why starch has to be changed so the body can use it?

5. Stir the starch and water again until the starch is mixed with the water. Take a teaspoon of starch-water mixture and put a drop of iodine into it. The mixture turns blue. This is a test for starch. It shows that there is starch in the mixture.

Now make a funnel with a piece of paper towel and put it in an empty glass. Stir the glass of starch and water again. Slowly pour some of the starch water into the paper funnel. You may have to hold the sides of the funnel to keep it from dropping to the bottom of the glass. You will see the water drip from the paper funnel into the empty glass. This is something like the way water goes through the lining of the small intestine. After the water has run through, look at the inside of the paper funnel. You will see that some starch is left inside. Did any go through with the water? You can tell by testing the water with a drop of iodine.

Now you can try the sugar water to see if the sugar will go through a paper funnel with the water.

How can you tell if there is sugar in the water before you pour it into the funnel? How can you tell if there is sugar in the water after it goes through the paper funnel?



How does this help to explain why starch must be changed to sugar before starch can be used in the body?

6. Make a model of your lungs. You will need a lamp chimney, a one-holed rubber stopper, two plastic feeding tubes, two rubber balloons, and a piece of rubber sheeting. Attach the balloons with rubber bands to the ends of the feeding tubes. Without further instructions try to make a model that shows how you breathe.

Adjusting to Changes

Even when you are sitting still, your body is active. Watch a friend as he reads. Does he lean first on one elbow and then on the other? Does he cross first one leg and then the other? Does he slump in his seat and then stretch? All these movements help to rest muscles when they get tired. Your body regulates itself and adjusts to changes without your thinking about it.

Your muscles are not the only parts of your body that must adjust in this way. When you run very fast, your body needs more oxygen. You breathe more quickly to provide your body with the additional oxygen. You do not think, "I must breathe harder to get more oxygen." Your body makes this adjustment automatically.

You perspire more on a hot day than on a cold day. Perspiring helps cool your skin. This is one way you adjust to changes in outside temperature.

When you go into a room where there is little light, you cannot see very well at first. But soon the pupils of your eyes enlarge to let in more light, and you can see better. Your body adjusts to changes in the amount of light.

All Living Things Adjust to Change

You remember that the body temperature of the turtle, a cold-blooded animal, changes with the temperature outside its body. When the outside temperature is high, its body temperature is high. It becomes more active. When the outside temperature is low, its body temperature

is low. It becomes less active. The turtle's body has adjusted to an outside change in temperature. Some warm-blooded animals, like bears, adjust to cold weather by hibernating.

All living things have ways of adjusting to changes.

Put a plant in a window. Make a drawing of the plant. Perhaps you can even take a photograph. Look at the plant again in a week. Observe its leaves and stems carefully. In what direction are they facing now? Compare the direction with that in your picture.

Like plants and other animals, humans adjust to many changes both inside and outside themselves. But human beings adjust to many changes better than any other living things do. For example, when winter comes, a fox grows heavier fur and finds a hole or a hollow log in which to live. A frog buries itself in the mud at the bottom of a pond until spring comes. Many birds fly away to a warmer place.

But human beings can build houses to live in. They can heat their houses. They can make clothing to wear. Human beings can adjust to changes by changing the world about them. They can do this because the human **nervous system** is more complicated than that of any of the other animals. Let's see how your nervous system helps you adjust to changes and helps you change the world about you.

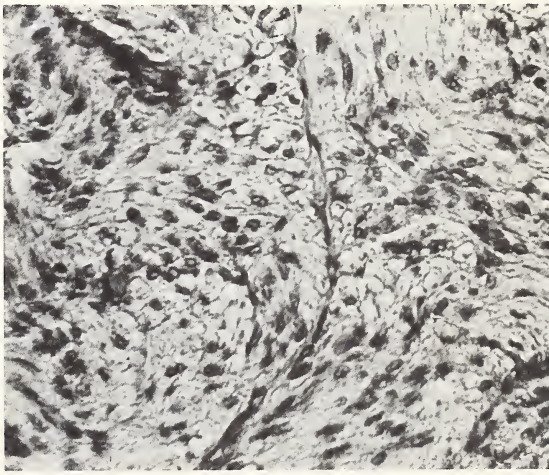
Your Nerves

Wiggle your thumb. Can you explain what made it wiggle? Did you tell it to wiggle?

For any part of your body to move, a message must travel from one part of your body to another. These messages are carried over thin thread-like fibers called **nerves.** The nerves are made of special cells, called **nerve cells.**

You know about some kinds of messages. When you speak to a friend on the telephone, your message travels by

These are nerve cells. Do they look different from other cells you have seen? How?



electricity at a speed of 186,000 miles a second. At that speed, it could travel around the world more than seven times in just one second!

When you shout to a friend at the other end of the schoolyard, your message travels at a speed of more than 1,100 feet a second. At that speed, it would take it about a day and a half to travel around the world just once!

A nerve message is different from the electrical message sent over the telephone. A nerve message is also different from the sound message when you speak or shout. Here are two ways in which the nerve message is different:

1. A nerve message travels along living cells.
2. A nerve message can travel in only one direction in any single nerve cell. (An electrical message can travel in either direction along a wire.)

In your body, a nerve message travels at a speed of about 300 feet a second. If you are 5 feet tall, a nerve message can travel from your brain to your toes and back again more than 30 times in a single second! Nerve messages travel so fast that you can move a finger in the same second in which you think of wanting to move it.

Different Kinds of Nerves

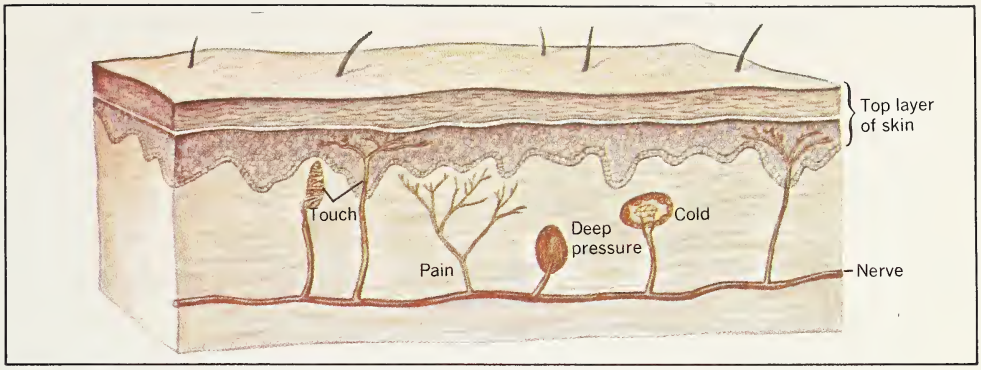
If you touch your finger with a pencil point, you feel it, of course. You feel it because a nerve carries the message of touch to your brain. You know that a pointed object touched you even though you did not see it.

Try this. Close your eyes and run your finger tips lightly over the desk top. You can feel every little bump along the desk, even the grains of dust and other particles on the desk top. Why?

Now run the back of your hand lightly over the desk top. You will not feel nearly as many bumps and specks of dirt with the back of your hand as you did with your finger tips.

You may have noticed something strange when you tried this comparison. With your finger tips, you felt many small bumps and particles. But you did not especially feel coldness from the desk top. With the back of your hand, you did not feel bumps and specks of dirt, but you did feel cold spots. Try it again if you did not feel these cold spots with the back of your hand the first time.

Try the same comparison with a piece of ice. Touch your finger tips to the ice. Then lightly run the back of your hand over the ice. What difference do you feel? What does this comparison tell you about nerves in your hand?



This section of skin shows the many kinds of nerves that are found in the skin.

You may have guessed that there are several kinds of nerves in your skin. Some of them carry the message of touch. Some of them carry the message of cold. Other nerves in your skin carry messages of heat, and still others carry messages of pain. Each nerve in your skin carries only one type of message.

But you do not find out about things through your skin alone. You have other senses besides your sense of touch. There are nerves that carry messages from your eyes to your brain. Other nerves carry messages from your ears to your brain. You taste and smell things because of nerve messages.

Have you ever received a very sharp blow on the head? When this happens, you sometimes "see stars." You "see stars" because certain nerves in your head have been made active by the blow. Since these nerves carry only the message of light, you see "stars."

The Sense of Taste

Nerves that end in your tongue help you to taste things. And just as you have different kinds of nerves in your skin, you also have different kinds of nerves in your tongue. One kind carries the message of salty taste. Another kind helps you to taste sweet things. Others carry taste messages of bitter things and sour things. And, like your skin, different parts of your tongue have different kinds of nerve endings. For some kinds of taste, there are more nerve endings near the tip of your tongue. For other kinds of taste, there are more nerve endings at the back or along the sides. Now try the experiment on the next page.

EXPERIMENT

Where Are the Nerve Endings in Your Tongue?

What You Will Need

salt	mirror
lemon	small, clean brush
sugar	5 cups of water
Epsom salts	clean handkerchief

How You Can Find Out

1. Dissolve some salt in one cup of water.
2. Squeeze some lemon juice into another cup.
3. Dissolve some sugar in another cup of water.
4. Dissolve Epsom salts in another cup of water.
5. Then dry your tongue with the clean handkerchief.
6. Dip the clean brush into one of these solutions and then touch the tip of the brush lightly to different places on your tongue. Repeat for each solution. Between each taste, take a drink of fresh water and dry your tongue with the handkerchief.
7. Record where you taste each substance best. The mirror will help you see the exact spot you are touching.

Questions to Think About

1. Why should you dry your tongue between each taste?
2. Which part of your tongue has the most nerve endings for each taste?
3. Can you now draw a picture to show where the four different kinds of nerve endings are located along your tongue?

The Sense of Smell

You have probably noticed that when you have a cold, you do not enjoy eating. That is because you need more than the nerve endings in your tongue to get the full flavor of anything you eat. Each food has a smell as well as a taste. The message from your tongue and the message of smell from your nose combine to give each food its own particular flavor. A bad cold prevents you from smelling things as well as you usually can.

The nerve endings for smell are high in your nose. Usually, only a small part of the air you breathe passes over these nerve endings. If you really want to smell something well, you must get the air up to the nerve endings high in your nose passage.

Have you ever noticed how a dog sniffs at something when he wants to smell it better? A dog's nerve endings for smell are also high in the nose. He sniffs the air up to these nerve endings to smell things better.

Here is a comparison you can make to show how bringing the air high into your nose helps you smell things better. Take an orange. Nick the skin of the orange to release some of the odor and hold it near your nose. First, breathe as you usually do. See how much you smell the orange. Then take a deep breath. Compare the odor of the orange when you breathe as usual with its odor when you take the deep breath.

Here is something else you can try with the same orange. Hold the nicked

orange to your nose and smell it. The odor will seem strong. Keep the orange there for several minutes. After a while, you will no longer smell the orange as strongly as you did at first. Is this because the odor from the orange is all gone? Or is it because your nerves of smell do not carry the message as well as they did when you first smelled the orange? Make another nick in the skin to release fresh odors to find out.

The nerves that carry the message of smell get "tired" after carrying one odor for a long time. They no longer carry the message of that smell as well as they did at first. Do you remember coming into your house just before mealtime and smelling food cooking? Then, after a while, you no longer noticed the smell. Your nerves for smell had become "tired" of that particular odor.

Your Other Set of Nerves

So far, you have learned about nerves that carry messages of touch, taste, and smell to your brain. These nerves are sometimes called **sensory nerves** (SEN-ser-ee). But we still have not found out why your thumb wiggled. How did it get the message that made it wiggle?

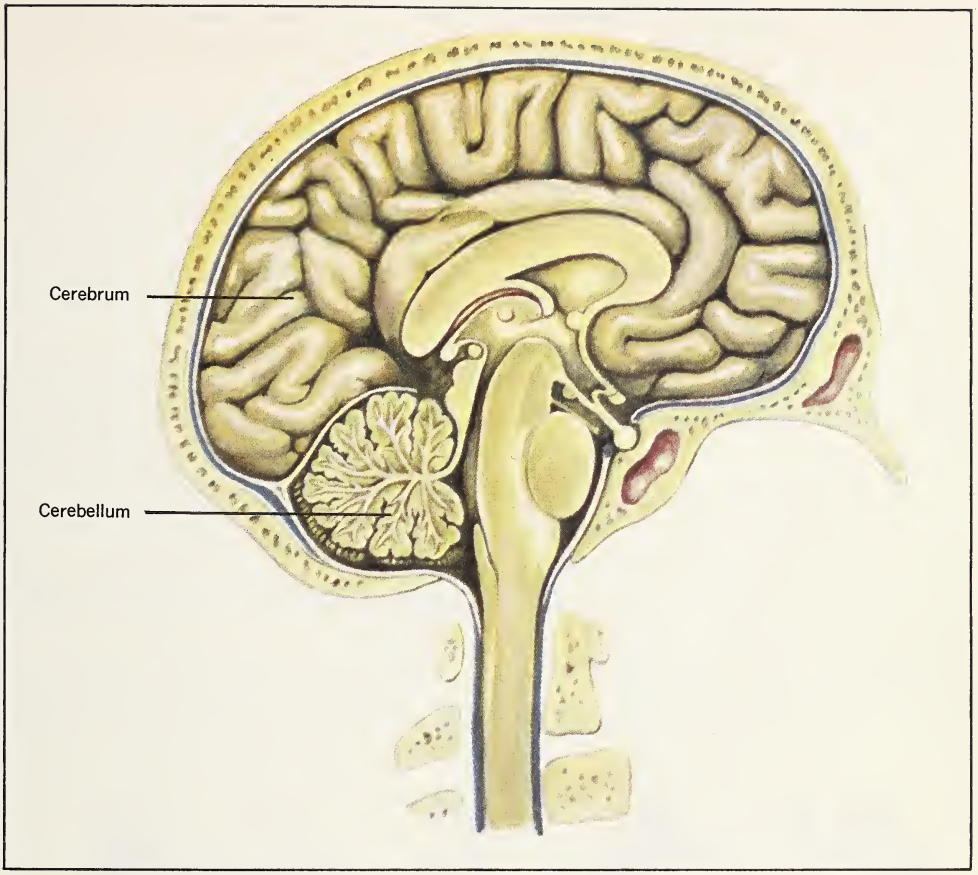
To move any part of your body, you must use two sets of nerves. As you have already learned, one set carries messages from your senses to your brain. The other set carries messages from your brain to your muscles.

Let's see what happened in your body to make your thumb wiggle. With your eyes, you read, "Wiggle your thumb." In your eyes, the message was changed into nerve impulses. This message traveled along nerves from your eyes to your brain. If you then decided to wiggle your thumb, a message had to travel along other nerves from your brain to the muscles in your thumb.

The nerves that carry messages away from the brain are sometimes called **motor nerves.** Before you kick a football, or pick up your books, or write your spelling words, or do any other activity, messages must travel along the motor nerves to your muscles.

Messages are sent to the brain by the sensory nerves from all parts of the body. Orders come from the brain by way of the motor nerves, making the various body parts do certain things.

The sensory and motor nerves are part of your nervous system. Your brain and **spinal cord** (SPY-n'l) are the center of your nervous system. They make up your *central nervous system.* The "lines of communication" are the nerves —12 pairs of nerves go to the brain and 31 pairs go to the spinal cord.



Your Brain

Each part of your brain receives messages from a different part of your body. A message from your right thumb to your brain starts in the nerve endings in your right thumb, passes to the nerves in your spinal cord, and travels from there to the left side of your brain.

All messages from the right side of your body go to the left side of your brain. And all messages from the left side of your body go to the right side of your brain.

Notice the **cerebellum** (sehr-uh-BEL-um) in the picture. When a person's cerebellum does not work as it should,

he can hardly walk. All his movements are jerky. The cerebellum automatically takes care of co-ordination. By co-ordination we mean smooth action of muscles.

Look at the **cerebrum** (SEHR-uh-brum) in the picture of the brain. The cerebrum is the part of the brain concerned with thinking. It is in the cerebrum that messages of sight, sound, taste, smell, and touch are received and decisions as to what the messages mean are made.

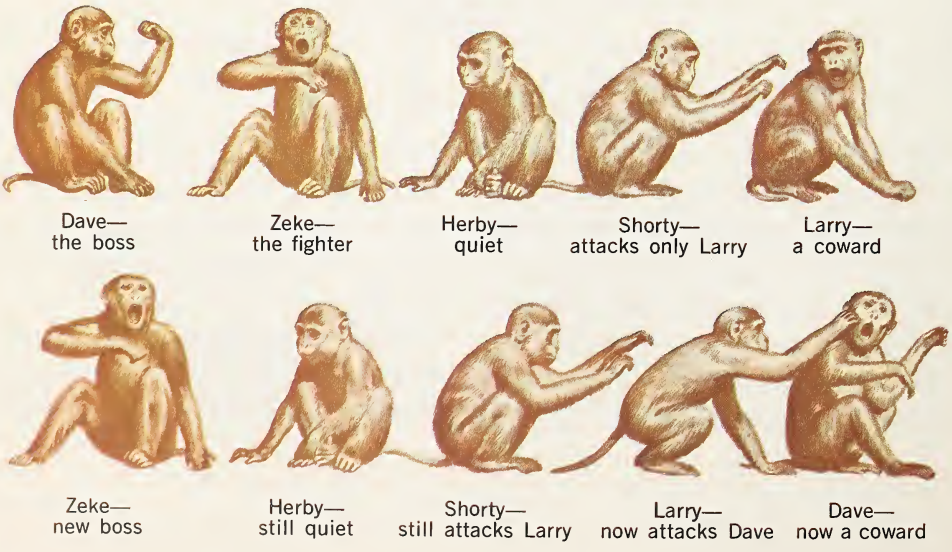
Scientists are trying to find out more about the cerebrum. They are trying to map the cerebrum; that is, they are trying to find out which parts of the cerebrum control various activities. For example, they have located the sections of the cerebrum that control sight, speech, and some muscles. Further research will help to make the maps more detailed.

Scientists are also trying to discover how changes in the brain affect the way one behaves. They know that personality seems to be controlled largely in the front section of the brain. It is in this part that mental activities like worrying or being afraid originate.

Scientists have found that it is possible to change a monkey's way of behaving by operating on this front section. First, they observed a group of monkeys and made notes about how they behaved.

Look at the pictures on this page and you will see what the scientists observed.

Dave was the Number 1 monkey and boss of the group. The other monkeys



were afraid of him. Larry was the most timid monkey. He was the last in the group.

Then scientists operated on Dave's cerebrum. Notice where Dave is in the group now. He is no longer the Number 1 monkey; he has moved to the very bottom of the group. Even Larry, who was the most scared of all the monkeys in the first set of pictures, can now boss Dave around. Larry did not have an operation, but he changed when he had someone to pick on.

In another experiment, scientists removed most of the cerebrum of a frog. The frog still hopped around. It digested food. In fact, the frog was able to carry on almost all its activities and lived for several weeks.

Experiments such as these help scientists learn about the brain and the nervous system. There are still many things to be discovered about the brain. As scientists learn more, they hope to be able to help people with various kinds of brain injuries.

Using What You Have Learned

1. Try to find out where different kinds of nerve endings are located on your skin. With a sharp toothpick, lightly tap sections of skin on your arm. When you tap some places you will not feel very much. When you tap other places, you will feel a slight pain.

2. Are there more nerve endings for the message of cold on the underside of your wrist than on the top? How can you find out? (Have you ever seen a mother test the temperature of milk before giving it to her baby by sprinkling some of the milk on her wrist?)

3. Get a small pea. Hold it between your crossed fingers as shown in the drawing. Close your eyes and move the pea slightly. It feels like two peas instead of one. Slide a pencil between your crossed fingers and you will feel two pencils.

Here is the reason. Ordinarily, the two parts of your skin touching the pea do not touch the same object at the same time. They do not usually carry the same message at the same time. When you cross your fingers, these two parts of your skin do touch the same object at the same time. But it still seems to you as if the messages are coming from separate objects—just as they usually do from these two places. Therefore, you have the illusion that there are two peas.

PATHFINDERS IN SCIENCE

Ivan Petrovich Pavlov

(1849–1936) Russia

Ivan Pavlov was honored in a way that very few scientists are. His work was known throughout the world during his lifetime.

Pavlov had a brilliant mind and a great memory. He seemed to have endless energy and enthusiasm for work. Even at the age of 80, he had a vast enthusiasm, which he communicated to all those around him, for scientific investigation. He was the moving spirit for most of his laboratory's projects. When an experiment was successfully completed, he would dance with joy. It is said that his laboratory was run like a town meeting: on Wednesdays, the scientists gathered to discuss and argue their problems. Pavlov would fight very hard for his ideas. However, when he was in error he was quick to admit it.

Much of Pavlov's early work was done in a laboratory that was a small wooden building—not much more than a shed. The money for his projects came mostly from his own very small salary. He had no regular assistants. Yet, because of his fine mind, energy, and self-sacrifice, he was

4. Whether something feels hot or cold to you involves making a comparison. Try this. Get three bowls. Put warm water that is about 90° F. in the first bowl. Put water that is about 60° F. in a second bowl. In the third bowl, put cold water that is about 35° F. Put one hand in the first bowl and your other hand in the third bowl. Keep them there for thirty seconds. Then put both hands in the second bowl. How does the water in this middle bowl feel to each hand?

awarded the Nobel Prize in 1904 for his research on the digestive system.

One of Pavlov's discoveries was that the nervous system plays a vital part in digestion. In the stomach are juices that help to break down food and prepare it for use by the body. Pavlov showed that the flow of these juices is controlled by nerves that extend from the head through the neck. When you chew food, these nerves are stimulated. The juices start flowing in the stomach even before the food arrives there. The flowing of the juices is an automatic reaction, called a "reflex."

Today we remember Pavlov more for his work on learning than for his work on digestion. While studying reflexes that aid digestion in the dog, Pavlov noticed an interesting thing about saliva forming in the mouth of the dog. You know that, when you have food in your mouth, the saliva flows automatically and mixes with the food. But during his experiments with dogs, Pavlov noticed that saliva flowed *before* the dog had food in its mouth; it started flowing when the dog saw food! Pavlov reasoned that the animal must have *learned* to react to the sight of food as he reacted to the food itself. Pavlov called this kind of learning **conditioning.**

Pavlov experimented to find out how conditioning takes place. In one experiment, a dog was placed in a room by itself, and a light was turned on. No saliva flowed. Then the dog was given meat, and saliva, of course, began to flow. A few more times, the light was turned on and then the meat was presented. After several trials, the dog's saliva began to flow as soon as the light was turned on, before the food was presented. The dog had been conditioned to associate the light with food.

Since Pavlov's time, scientists have done thousands of experiments on conditioning.

Doing Things Without Thinking

Imagine what your life would be like if you had to think about things such as keeping your body temperature unchanged, taking a breath, or making your heart beat! You would spend every moment thinking about these activities and would have no time left for anything else.

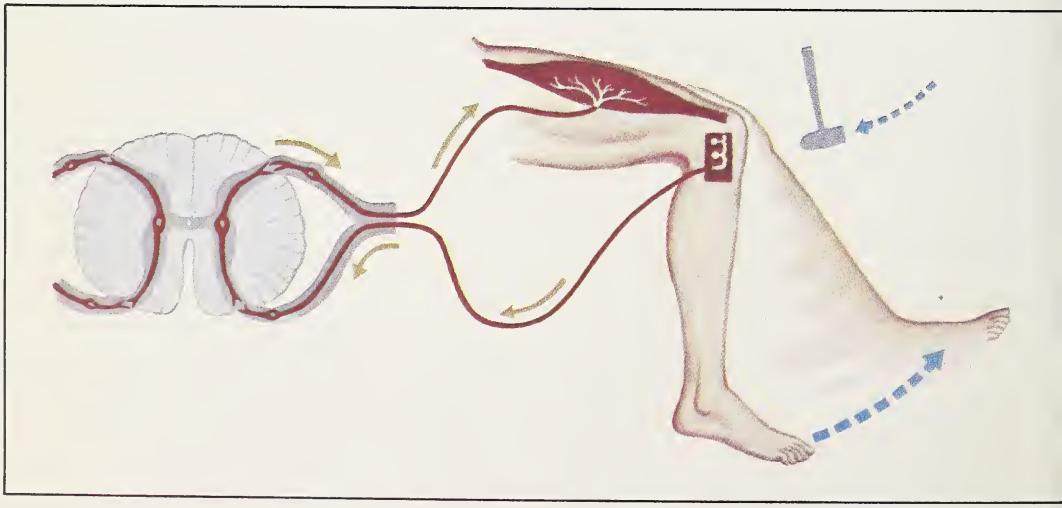
And what would happen if you did not remember to digest your food? What if you forgot to make your heart beat? What if you suddenly got tired of paying attention to breathing?

Your body does many important things that you never think about. Your cerebrum does not tell your body to do these things. How, then, does your body do these things?

You have already read about how your nerves control the movements of your arms and legs. Other nerves control your heartbeat and your digestion.

What happens when something irritating gets into your nose? What do you do if an object is coming toward your eye fast? Cross your legs and have someone tap you lightly on the crossed leg below the knee with the edge of his hand or a large stick. When your friend hits a certain spot below your

Can you tell what is happening in the diagram? What kind of nerve action is shown?



knee, your foot kicks out. You do not realize that your foot kicks out until you see it!

These activities do not depend at all on thinking. The nerves that control these activities do not go into the cerebrum. The messages that start these activities are picked up by nerve endings and travel to your spinal cord. The response is automatic. From your spinal cord, a message goes out that makes you sneeze, blink, or kick your foot.

The activity that follows from this kind of nerve message is called a **reflex** (REE-flekss). Sneezing is a reflex. So is blinking your eye when an object comes toward it. The kicking reflex is called the knee-jerk reflex. Doctors often test the knee-jerk reflex to see if the nervous system is normal.

Many reflexes keep your body operating smoothly. The eye-blinking reflex protects your eye from dust and flying objects. The sneezing reflex clears your nose of irritating objects.

Other reflexes are useful, too. If you accidentally touch a hot object, you pull your hand away immediately. You pull your hand away even before you are aware that you have touched something hot. The action is a reflex. Your body does it automatically. This reflex protects you from certain kinds of burns.

Body Temperature

You have learned that your body stays at about the same temperature at all times. This is something else your body does without your thinking about it. You can take your temperature at different times to see that this is true. Take it when you get up in the morning. Take it after playing. Take it on a warm day and on a very cold day. Take it just before you go to bed at night.

You will probably find that your body temperature does change during the day —but only slightly. You will find that your temperature is a bit higher immediately after you exercise. You may also find that other boys and girls have temperatures that are different from yours, even though all of you are healthy. But you will also discover that your temperature and your friends' temperatures seem to stay about the same—between 98° and 100° F.

One way your body keeps a steady temperature is by perspiring. You perspire more when it is warm. Nerve endings in your skin carry the message of heat to the temperature-control center in your nervous system. A message travels back to your skin and makes you perspire. Water is collected in your skin in thousands of sweat glands. It comes out of tiny openings in your skin

called pores. The moisture spreads over the surface of your body. How does this help to keep your body cool? Here is a way you can find out.

Take two dry cloths of the same size. Soak one in water and hang both cloths in the same place. Let them hang for five or ten minutes. Then feel them. Which cloth is cooler? Why?

When a wet cloth is wrapped around the bulb of one of two thermometers, the thermometer with the bulb wrapped in wet cloth will have a lower reading than the other. When water evaporates from an object, the object becomes cooler. Can you tell why?

The hotter it is, the more you perspire. The more water that evaporates from your skin, the cooler your body surface becomes. You can see that perspiring helps your body remain at about 98½° F. even on a hot day.

There is another way in which your body loses heat. Has your mother ever said, "Sit down for a while. You're getting overheated"? She can tell when you are very warm without actually touching you.

When you are warm, the blood vessels just under your skin automatically become larger. As they become larger and carry more blood, your face becomes flushed. But you get cooler when you become flushed. Much of your body heat is passed from your blood to your skin, because more blood is now at the surface of your body in the enlarged vessels. Your skin, in turn, gives off heat into the air, just as a stove or any other warm object does. Your body cools down. Perspiring and flushing are two automatic activities that help to keep your body at a steady temperature.

What happens when the air around you is cold? The blood vessels just beneath your skin automatically become smaller. They carry less blood. Not as much heat is passed from the inside of your body to the skin and from there into the air, because less blood is now at the surface of your body in the shrunken vessels. This action of your blood vessels helps keep heat inside your body on cold days. Nerves control this action.

Have you ever shivered so much that you could not talk? Shivering is still another activity that keeps your body at about the same temperature. When you are chilly, the muscles in your arms, legs, and face become tense. When your muscles become tense, they produce more heat. You become warmer. If you get very chilly, your muscles become so tense that you begin to shiver. Shivering produces still more heat and helps keep your body temperature steady.

Nerve Messages Affect One Another

When you feel dizzy, you feel as if you have lost your balance. The feeling of balance is controlled by a fluid inside the ear. When you are tilted, this fluid presses against certain nerves, and you feel off balance. You then try to right yourself.

People sometimes get motion sickness when they ride a roller coaster or an airplane. They are not used to being tilted or swayed. Yet, often when people get motion sickness, the fluid in their ears is in the normal position. The sickness is certainly there, but the nerve messages that cause the sickness are coming from somewhere other than the fluid in their ears.

Here is what happens. The person looks at the horizon, and it seems tilted or high or low. He is not used to seeing the horizon that way. Usually when he does see it that way, he feels off balance because he *is* off balance. But on the roller coaster or airplane he is not off balance. What nerve messages are traveling through his body?

Nerve messages from his eye carry the message of a tilted horizon. The message of a tilted horizon may make other nerves carry messages that cause motion sickness. But nerve messages from the ear carry the message that balance is all right. These messages from the ear reduce the motion-sickness messages.

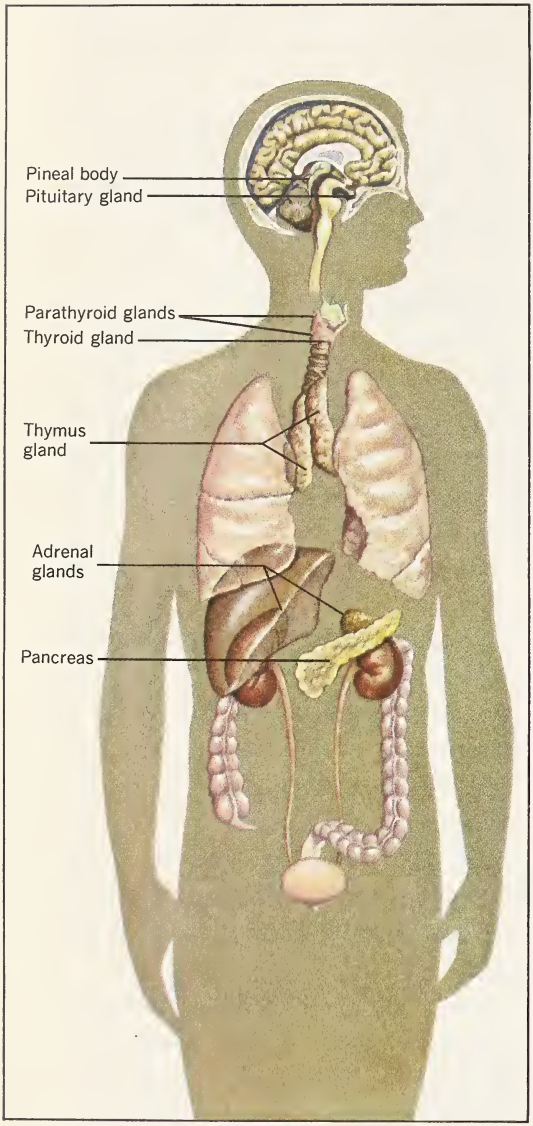
Notice how the nerve messages act on one another. The messages from the ear partly cancel out the messages causing motion sickness.

The Glands

Some of the things that happen in your body are not controlled entirely by nerves. Some things happen because of certain chemicals in your body. These chemicals are produced in parts of your body called **glands.**

Have you ever been so scared or so excited that you did something you would not ordinarily be able to do? There is a newspaper story that tells about two women who were alone in a house when a fire started. The two frightened ladies lifted their piano and carried it outside. Later, it took five men to carry the piano back into the house! Everyone's body is able to produce a great amount of extra energy in an emergency.

When you are suddenly frightened, your heart beats faster and you breathe more rapidly. More sugar is released into your blood to give you extra energy. These changes prepare you to meet an emergency.



The glands shown here all release their hormones directly into the bloodstream. Tell what each gland is responsible for in your body.

When you breathe faster, your body gets more oxygen. When your heart beats faster, the blood travels faster. It furnishes each cell with more food and oxygen so that it can produce more energy.

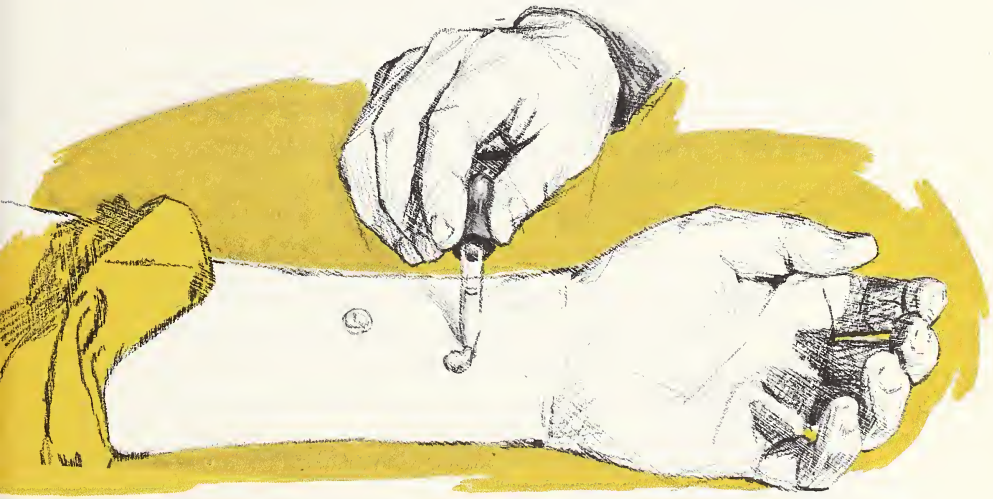
These automatic changes in your body are caused by a hormone released from your **adrenal glands** (ad-REE-n'l). The adrenal glands release their chemicals directly into the blood. You have two adrenal glands, one located on each kidney, just above the small of your back.

Other glands cause different automatic actions. As you may remember, the pituitary gland near your brain releases a hormone into your blood that controls how rapidly you grow. In fact, you cannot grow without the chemical from this gland. The parathyroid glands in your neck control the way your body uses the mineral calcium. The thyroid gland in your neck controls how rapidly your body uses up energy. All the various glands of your body do their work by releasing special hormones into your blood.

You have seen that you do certain things without thinking. You can do certain things without thinking because your nerves and your glands work to keep your body running smoothly.

Using What You Have Learned

1. You can feel the cooling effect of evaporation on your skin by putting a few drops of water on your wrist. Alcohol evaporates faster than water. Would evaporating alcohol make your skin feel even cooler than evaporating water? What experiment can you plan to find out? How can you be certain that the alcohol and the water are the same temperature before you start the experiment?



2. Why is it hard for you to keep cool on a muggy day?

3. Why do football coaches sometimes tell their players to "get mad"?

4. Why is it uncomfortable for your eyes when someone suddenly turns on a bright light in a dark room?

5. Tell how your reflexes have helped you in what might have been a dangerous situation.

WHAT YOU KNOW ABOUT

Systems of the Body

What You Have Learned

The body's systems work together to maintain health and life. The **circulatory system,** which is made up of the heart, blood, **arteries, capillaries,** and **veins,** circulates the blood all through the body.

As the blood circulates through the body, it picks up products from one part of the body and drops them off at another. Oxygen and food are carried to and wastes are carried away from the cells.

The **digestive system** breaks down food to be used by the cells. Food mixes with saliva in the mouth, then goes to the gullet, to the stomach, and then to the small intestine. Whatever is not digested moves on to the large intestine.

The **excretory system** carries wastes out of the body through the large intestine, the bladder, and the skin. The **respiratory system** also carries carbon dioxide waste out of the body.

The **nervous system,** which is made up of the brain, spinal cord, and nerves, controls not only the ability to think but also the ability to react to the world around you.

Other parts of the body, such as bones, muscles, and **glands,** also work to maintain life and health.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

bladder	cerebrum	kidneys	sensory nerve
capillaries	diaphragm	motor nerve	spinal cord
cerebellum	diffusion	reflex	villi

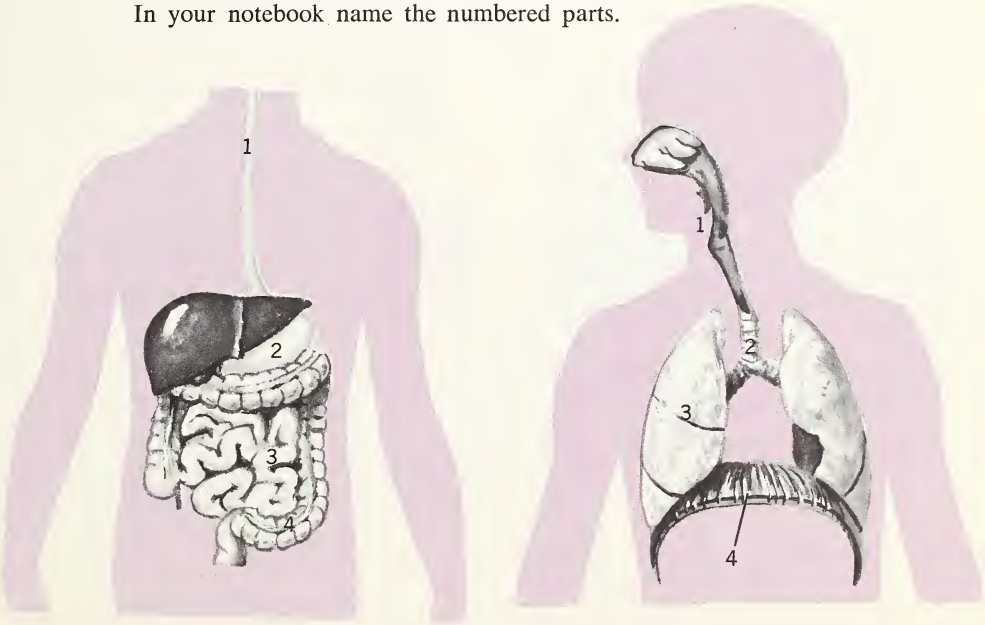
What Is the Answer?

Write the numbers 1 to 10 in your notebook. Next to each number write the answer to the question below.

1. Which blood vessels carry blood back to the heart?
2. Which blood vessels are smallest?
3. Which blood vessels carry blood away from the heart?
4. What is the beat in an artery called?
5. What instrument does the doctor use to hear your heartbeat?
6. In what part of the digestive system is digestion completed?
7. What are the little "fingers" on the inner wall of the small intestine called?
8. In what part of the body are there 2 million filters?
9. What part of the brain takes care of coordination?
10. In what part of the brain does thinking occur?

Name the Parts

Below you will see the outlines of two systems of the human body. In your notebook name the numbered parts.



YOU CAN LEARN MORE ABOUT

Systems of the Body

Can You Tell the Words?

Figure out the science words by adding or subtracting the names of the pictures and the words.

1

2

3

4

5

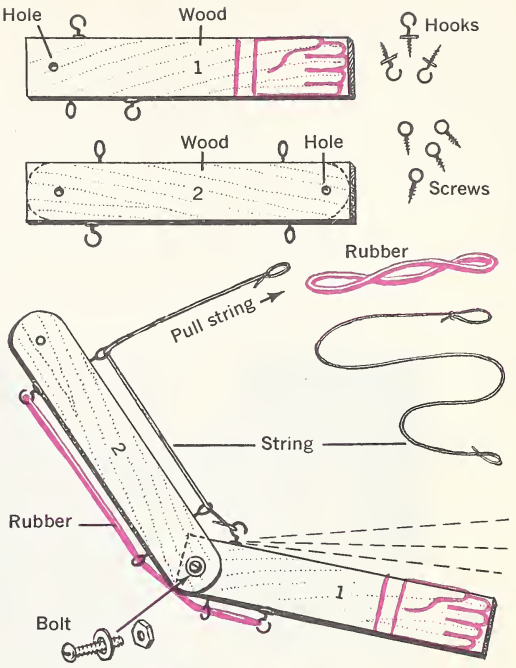
Making a Model

A model will show you how the elbow joint enables you to move your arm. You will need two pieces of wood about 12″ long x 2″ wide x ¼″ thick, three cup hooks, four screw eyes, a bolt and nut, strong cord, and a rubber band.

Drill a hole in one corner of one piece of wood. Insert two cup hooks and one screw eye in the wood. This piece of wood will represent the two bones in the lower arm. Round the ends of the other piece of wood. Then drill a hole near each end. Fasten one cup hook and three screw eyes to this piece of wood. This piece will be the upper arm bone.

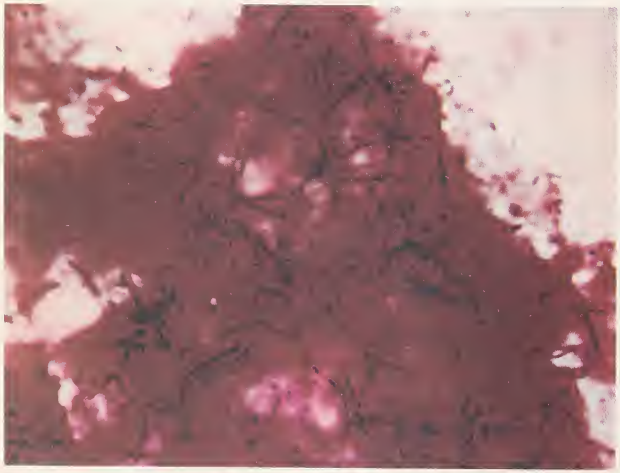
Next, join the two pieces with the bolt and nut. On the under side of the "arm," thread the rubber band through the screw eyes and slip it onto the two cup hooks. On the upper side, thread the cord through the screw eyes and tie one end to the hook.

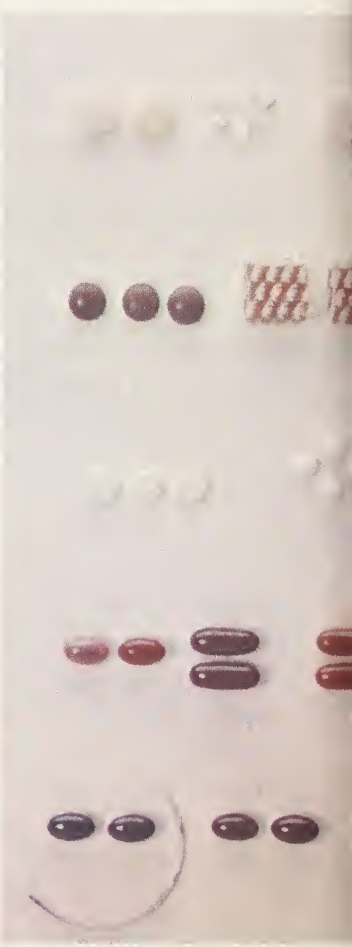
Now pull the cord. What happens?



You Can Read

1. *All About the Human Body,* by Bernard Glemser. Discusses bodily functions.
2. *Your Body and How It Works,* by Patricia Lauber. About the human body.
3. *Your Heart and How It Works,* by Herbert S. Zim. The heart and the circulatory system are simply described.





5

Conquering Disease

What Is Disease?
Man's Battle Against Disease

In 1964 an entire town became involved in a national study of diseases. Almost everyone in Sudbury, Massachusetts, will be examined many times from then until 1979. Scientists hope that what they learn from this study may lead to discoveries that will help you to live free from disease.

What Is Disease?

Your body is made up of many systems that work together. But sometimes something happens to the body so that these systems do not work properly. When this happens, you are sick. When you are sick, you have a disease. There are many ways in which you can become sick. There are many diseases.

Diseases are caused by various things. A baby who does not get enough vitamin D may develop rickets, a **deficiency disease** (dih-FISH-un-see). The word *deficiency* means "a lack." If you lack certain vitamins or an essential nutrient, you may have a deficiency disease.

There are other kinds of diseases. There are diseases that you "catch" from other people. These diseases are called **infectious diseases** (in-FEK-shuss). They are caused by germs that infect the body. Colds, measles, and whooping cough are such diseases.

There are other diseases that occur when certain organs or systems of the body—such as the heart and blood vessels, the kidneys, the liver, and the nervous system—begin to wear out, or degenerate (dih-JEN-er-ayt). These are called **degenerative diseases.** Hardening of the arteries is one such disease. Sometimes degenerative diseases are the result of heredity, aging, or poor care of the body. At other times they are the indirect result of infectious diseases.

Primitive Man and Disease

Since earliest times, diseases have struck man. Primitive man was helpless against disease. Primitive man neither understood sickness nor knew what to do about it. He thought that evil spirits entered the body and made it sick. Some evil spirits caused a headache; others caused fever or a skin rash. To

This man is thought to have evil spirits within him that cause him to be sick. By wearing masks and chanting, the medicine men hope to drive the spirits away.

get well, he thought, one had to drive these evil spirits out of the body. To do this, one had to call for the help of a good spirit. The good spirit would defeat and replace the evil spirit.

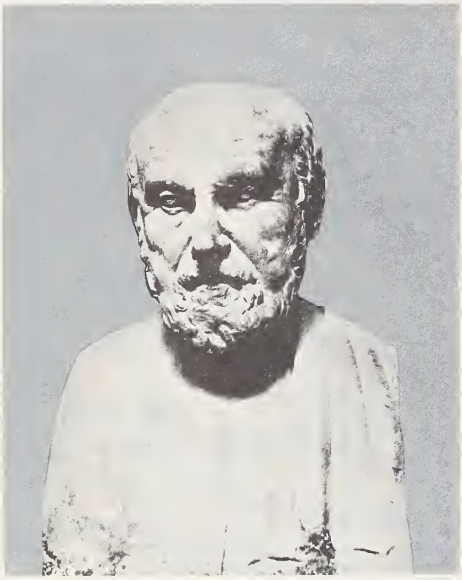
Medicine men drove evil spirits away by beating, starving, or torturing the sick person. They believed that the evil spirits would leave if the patient's body were an unpleasant place in which to stay. Sometimes they tried to scare evil spirits away by wearing masks and costumes and by dancing and singing.

Early peoples believed in evil spirits, omens, and gods. For thousands of years, this belief affected their way of treating disease.

The Humor Theory of Disease

More than two thousand years ago, Hippocrates (hih-POK-ruh-teez), a Greek physician, believed that disease had a natural, rather than a magical, cause.

According to Hippocrates, the body had four important liquids, called the **humors** (YOO-merz). Hippocrates believed that people were in good health when the humors were balanced. When there was too much of one humor, sickness resulted. He thought the body itself could get the humors balanced again. To help the body get back its balance, he prescribed fresh air, rest, and certain foods for his patients.



Hippocrates, a Greek physician, is known as the founder of scientific medicine. Can you tell why?

Galen talks about treating diseases by using medicines. Find out more about Galen's ideas.

About five hundred years later, Galen (GAY-lun), a Roman, believed that everything in nature was made of four things: fire, air, water, and earth. Fire was hot, air was dry, water was wet, and earth was cold. A person was healthy if these four things were balanced in his body. If they were out of balance, sickness resulted.

To treat diseases, Galen used medicines made from plants, animals, and materials of the earth. Galen chose medicines according to the disease and the special property that each drug was said to have: hotness, coldness, wetness, or dryness.

Some of Galen's medicines really worked. For example, to lower a fever, Galen used medicines with "coldness." The "cold" substances worked against the high temperature of the body. The balance of hotness and coldness was restored. Can you guess one of the things Galen said had "coldness"?

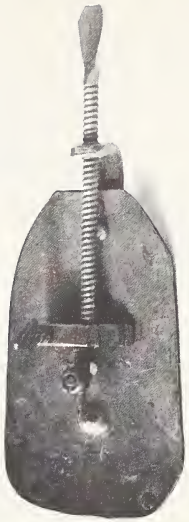
Discovering Microorganisms

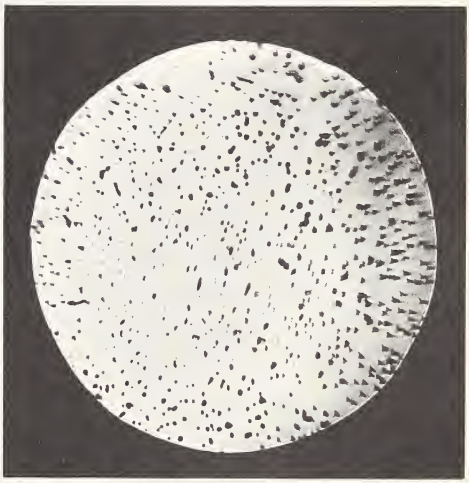
There were other theories of disease. There were some men who thought that disease might be caused by tiny living organisms, too small to be seen by human eyes. The invention of the microscope made it possible to find out if such organisms existed.

You may remember that Anton van Leeuwenhoek made lenses as a hobby. His lenses were very small, but they magnified objects as much as two hundred times. Leeuwenhoek looked at all sorts of objects—skin, hair, ivory, and the wings of flies. He discovered a new world. Then, in 1675, he happened to study a drop of pond water. He saw tiny objects moving around. They seemed to be alive. Leeuwenhoek called them "animalcules." He was probably the first man in history to see these tiny living creatures. These tiny organisms were one-celled animals now called **protozoa** (proh-tuh-ZOH-uh).

You, too, can see protozoa. Collect some water from several places in a pond. Look at a few drops under a microscope. How many different kinds of living things do you see?

After Leeuwenhoek's discovery of protozoa, many other kinds of microscopic life were found. Organisms too small to be seen by the unaided eye are called **microorganisms** (my-kroh-OR-gun-iz'mz). Microorganisms are found in soil, in water, in the air, and on other living organisms. With the help of the microscope, man discovered a new world of living things. Yet years passed before scientists found evidence connecting microorganisms with disease.





This photograph was taken through one of Leeuwenhoek's original microscopes, shown above. The photograph proves that Leeuwenhoek could see the shapes of the microorganisms he drew.

How Can Protozoa Be Raised?

What You Will Need

cup of water	dead grass, hay,	2 clean jars
clean white cloth	or straw	2 glass slides
hot plate	microscope	eye dropper
pan	2 cover slides	rubber bands

How You Can Find Out

1. Boil the water in a pan on a hot plate. Let it cool for at least an hour.
2. When the water is cool, pour an equal amount into each jar.
3. Place all the grass, hay, or straw in one jar. Do not put any in the other jar.
4. Cover each jar with a piece of cloth. The cloth can be held in place with rubber bands.
5. Place both jars in a warm, dark place for six or seven days. Do not move the jars.
6. After four or five days, use an eye dropper to take a few drops of water from one jar. Place the drops on a microscope slide. Rinse out the dropper.
7. With the dropper take water from the other jar and place some on another slide.
8. Cover the drops on each slide with a cover slide.
9. Examine both slides carefully with a microscope.
10. If nothing is seen, take fresh samples and try again.

Questions to Think About

1. Describe what you see.
2. Why do you use dead grass, hay, or straw?
3. Why do you boil the water?
4. If you see nothing, what reasons can you give as to why nothing grew?
5. How did the organisms get into the water?

Louis Pasteur examines a glass container to see if the liquid in it has spoiled. Did he need to have controls for his experiments? Explain your answer.

Pasteur Performs an Experiment

In ancient times there were many theories about the cause of illness. You have already read about three of them. None of these theories had been carefully tested. In the 1860's, a French chemist, Louis Pasteur (pass-TER), was trying to find out why wines spoil. His experiments led him to one of the greatest medical discoveries of all time.

French winegrowers asked Pasteur to help them discover why wines become sour. Pasteur knew that certain microorganisms were necessary for making wines. He also knew that other microorganisms, called bacteria, caused some solutions to sour. Pasteur believed that if these bacteria could be removed, the wines would not spoil. But they were too small to be filtered out.

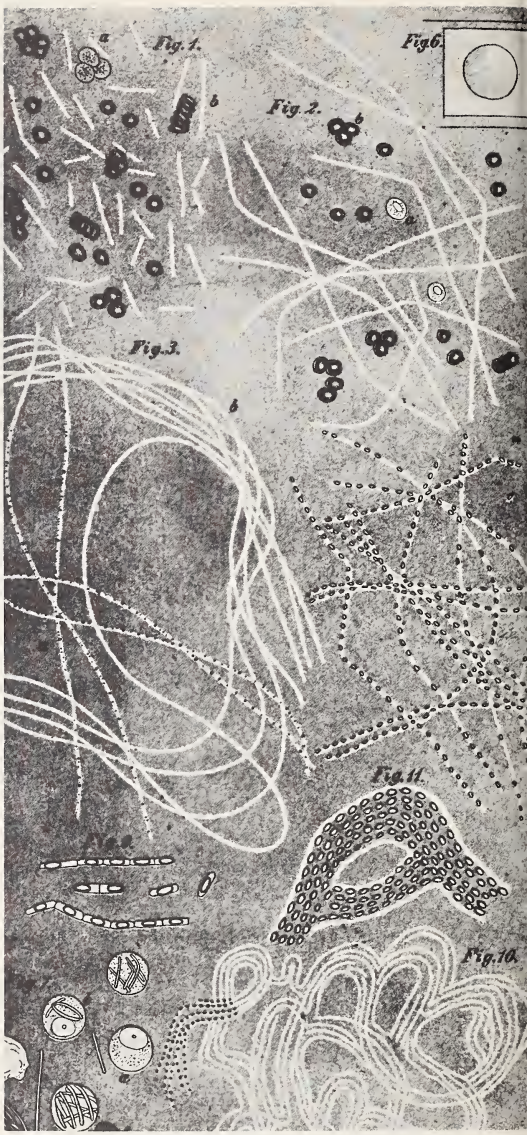
Pasteur had an idea. He took some of the soured wine and gently heated it. Then he examined the wine through his microscope to find the bacteria. They were no longer there. The bacteria seemed to have been killed by the heat. Pasteur tried this many times and got the same results. This evidence led him to believe that heating wine would kill the bacteria and keep it from spoiling.

Pasteur performed an experiment to test his hypothesis. A ship was about to

sail. Pasteur placed two barrels of wine on board. The wine in one had been heated. The wine in the other had not. The ship sailed, and after ten months it returned. Both barrels were opened, and the wine was tasted. The heated wine had remained perfectly sweet. The unheated wine was not fit to drink. It had turned sour! Pasteur had learned how to prevent certain liquids from becoming sour. This process of prevention is called **pasteurization** (pass-ter-uh-ZAY-shun). Do you know how it is used today?

Pasteur had discovered a way to kill certain bacteria. Next he wanted to find out where the bacteria came from. How did they get into wine? Some people believed that the bacteria came from the wine itself. Pasteur thought that the bacteria came from the air. Pasteur did other experiments to test his ideas further.

Pasteur collected many liquids that were known to spoil. He placed each liquid in a separate glass container and heated it. Then he put tops tightly on these containers so that no air could enter. For months, the liquids remained in the jars. From time to time, Pasteur opened some of the containers. He opened them in such a way that little air could enter them. He examined sam-



These are Robert Koch's own drawings of stages in the life of the bacteria that cause the disease called *anthrax*.

ples of the liquids under a microscope. All of them were free of bacteria.

Then Pasteur opened some of the containers and let air enter them. After a short time, the solutions contained bacteria. Pasteur now had good evidence that bacteria were in the air. They got into the wine from the air.

Pasteur continued to work with microorganisms. His experiments led him to form the **germ theory of disease.** The theory states that infectious diseases are transmitted by specific germs, or microorganisms. This was one of the greatest medical discoveries of all time.

Robert Koch (seated third from left) journeyed into the jungle to study tropical diseases.

The Germ Theory of Disease

Scientists found many bacteria in the blood of diseased persons. Why were the bacteria there? Were they always in the person's body? Or were they there only when the person had a disease? No one knew the answers, but some scientists studied and experimented with microorganisms to find out.

Robert Koch (KOHK), a German physician, studied a disease called **anthrax** (AN-thrakss). This was a disease that cattle, sheep, and sometimes human beings got. One kind of bacterium was always found in the blood of diseased animals. Was this bacterium the cause of anthrax?

In his laboratory, Koch infected mice with anthrax. He examined the blood of the mice many times with a microscope. He learned how the bacteria grew and multiplied.

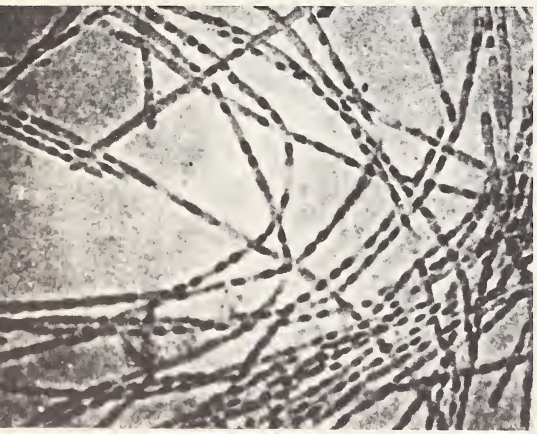
Koch also found something else. He learned that bacteria can grow coverings around themselves. In this form bacteria are called **spores.** Spores do not look like bacteria at all. Spores can survive almost anywhere—in air, water, and soil. Bacteria in the spore stage do not cause anthrax. But when conditions are just right, the bacteria grow out of the spores and multiply rapidly. Then they cause anthrax.

Growing Bacteria

Koch's next experiments gave scientists a new tool for investigating disease. He found a way of growing, or **culturing** (KUL-cher-ing), bacteria in his laboratory. To do this, he used a special substance called **nutrient agar** (NOO-tree-ent AH-gahr). Nutrient agar provides food for bacteria. It is made from seaweed.

Koch wanted to make certain that there was only one organism that caused anthrax. He took drops of pus from sores on a mouse with anthrax and spread the drops on a plate containing agar. Several different kinds of bacteria grew. The bacteria of each kind crowded together to form a different type of "spot," or **colony.**

Koch's photograph of a colony of bacteria.



But Koch wanted separate, or "pure," cultures. So he carefully took a little material from each type of colony and spread it over separate agar plates. When the bacteria grew, each plate had one and only one kind of bacterium. Now Koch had pure cultures. But which bacteria caused anthrax?

To find out, he injected healthy mice with bacteria from different colonies. Not all the mice got anthrax. Only bacteria from a particular kind of colony seemed to cause anthrax in mice.

Koch was still not satisfied. He cultured these bacteria from the sick mice and tested them again in healthy animals. Each healthy mouse developed anthrax. The cause of anthrax was always the *same* bacterium.

Koch's careful experiments proved that anthrax was caused by *one* microorganism. Now, for the first time, men had proof as to the cause of an infectious disease.

Finding New Infectious Bacteria

To help scientists find the bacteria that cause other germ diseases, Koch developed a set of rules. He believed that a scientist cannot be sure that a certain kind of bacteria causes a certain disease unless he follows the steps listed on the next page.

1. The organism must be seen in every case of the disease.
2. The organism must be grown in a pure culture.
3. Injected bacteria from a pure culture must cause the disease in a healthy animal.
4. The organism must be found in the newly infected animal and grown again in a pure culture.

Following these rules, scientists soon found the bacteria that cause **tuberculosis** (too-ber-kyoo-LOH-siss), **diphtheria** (dif-THEER-ee-uh), **pneumonia** (noo-MOH-nyuh), and **cholera** (KOL-er-uh).

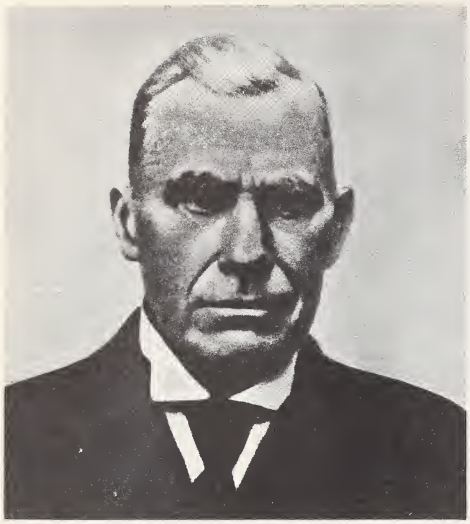
Koch's rules were based on certain **assumptions** (uh-SUMP-shunz). An assumption is a statement whose truth is taken for granted.

Koch assumed that all infectious diseases were caused by bacteria. He assumed that all disease-causing organisms could be seen with a microscope. He also assumed that infectious organisms would grow on special food in a laboratory. Furthermore, Koch assumed that animals could get all the infectious diseases human beings got. Although these assumptions helped scientists find many disease-causing microorganisms, later scientists questioned the assumptions.

Iwanovski's experiments laid the groundwork for others investigating the causes of disease.

Viruses Cause Disease

In 1892 a Russian scientist, Dmitri Iwanovski (ee-von-UF-skee), studied a disease of tobacco plants. He found that the juice from infected leaves could carry the disease to a healthy plant. He believed bacteria were in this juice. To find the germs, he passed the juice through a filter with very tiny holes. It could trap the smallest bacteria. Only a clear liquid could pass through. To his great surprise, the clear liquid still infected tobacco plants. Iwanovski thought that there was something wrong with his filter and that some bacteria did get through.



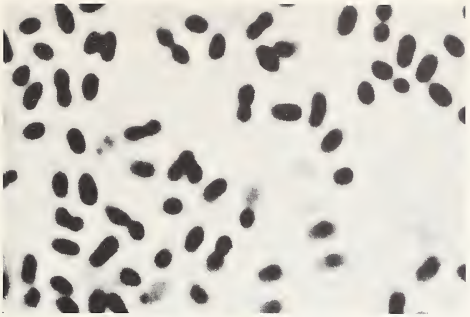
Beijerinck repeated one of Iwanovski's experiments and labeled the disease-causing molecule that is smaller than a bacterium a *virus*.

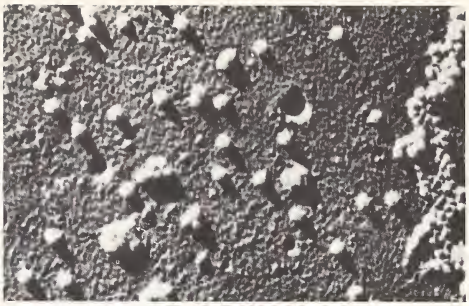
Five years later, Martinus Beijerinck (BAY-er-reenk), a Dutch scientist, repeated the experiment. With a microscope he carefully studied the clear liquid. No bacteria were found. Drops of the liquid were put on agar plates. No bacteria colonies grew; nothing could be cultured. But when he placed the juice on a healthy tobacco plant, the plant became diseased. Beijerinck formed the hypothesis that the cause of the disease was some kind of large molecule, but one that was much smaller in size than a bacterium. The molecule was too small to be trapped by a filter or seen with a microscope. It could not be cultured on agar. The scientist called the molecule a **virus** (VY-russ). *Virus* is a Latin word meaning "poison."

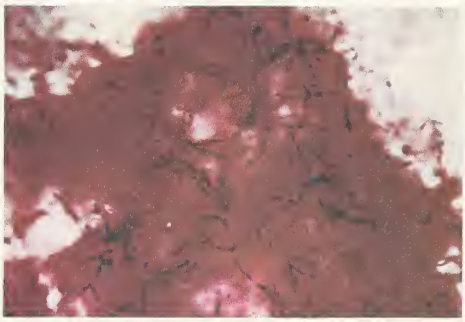
Friedrich Löffler (LOYF-ler), a German doctor and a pupil of Koch, studied foot-and-mouth disease. This is a disease of cattle. Löffler tried to use Koch's rules to find the microorganism that causes the disease, but they did not work. He was not able to culture it. His research showed that a filtered virus is the cause of foot-and-mouth disease.

This new evidence led scientists to doubt Koch's first assumption. Not all infectious diseases are caused by bacteria. Some infectious diseases are caused by viruses.

Löffler's work provided further evidence that not all diseases are caused by bacteria.







At the top left is a photomicrograph of bacteria that cause pneumonia, magnified 1,000 times. To the right are polio viruses magnified 77,000 times. At the bottom right, magnified 900 times, are fungus organisms that cause athlete's foot.

Finding New Infectious Viruses

What is a virus? A virus is a very tiny bit of protein, much smaller than a bacterium. The pictures on this page will give you an idea of the sizes of different microorganisms.

A virus cannot be seen with an ordinary microscope. It cannot be cultured on agar plates as ordinary bacteria can.

How can a scientist know that a virus causes a particular disease? How does he obtain evidence? A very important discovery helped scientists answer these questions.

Scientists discovered how to culture viruses. Viruses cannot get their food from materials such as nutrient agar. Viruses obtain food and multiply only inside a living cell. They do this because they use the cell's food-making processes. Now you know why earlier scientists could not culture viruses. They did not know that viruses must be grown inside living tissue. Today viruses are grown in little sections of animal tissue kept alive in laboratories. They are also grown in chick eggs.

In 1937, a very powerful microscope called the electron microscope was developed. In a compound microscope, the kind you may have in your school, beams of light are used to enable you

Eggs are injected with influenza viruses and then sealed. How do these eggs help scientists study diseases? How will you find out?

The electron microscope can magnify the organisms that cause "Asian flu" 27,000 times.

to see the object. Glass lenses then magnify the image so that you can see the object enlarged in size. There is a limit to how much glass lenses can enlarge an object, however. To see extremely tiny objects, it is necessary to use an electron microscope. In an electron microscope, beams of electrons are used to enable you to see objects. These beams of electrons behave much as light does. Instead of being focused by glass lenses, an electron microscope is focused by powerful magnets. An electron microscope can magnify thousands of times more than a compound microscope can. The electron microscope enables scientists to see viruses. They can identify the various kinds of viruses and discover how they behave.

Other new inventions and new culturing methods help scientists study and test viruses and find out what diseases they cause.

Ideas about disease have changed through the centuries. Unlike ancient beliefs, modern theories of disease are based on evidence. Many scientists from many countries have played important roles in obtaining this information. Today the causes of many infectious diseases are known. Knowing what causes a disease is the first step toward preventing and treating it.

Using What You Have Learned

1. Prepare a potato culture. Boil a potato. Cut several slices about one-quarter inch thick. Use a clean knife. Place each slice on a separate clean plate. Leave the potato slices exposed to the air for thirty minutes. Add a few drops of water to each plate. Then cover each plate with clear kitchen wrapping and put it in a warm, dark place. Examine each potato slice after a few days. What do you see? Colonies of bacteria may be any shape. They may be shiny or dull. Those found on potatoes are usually white, yellow, or orange. Do you also see molds growing? How can you tell?

2. Visit a medical laboratory to see how culture plates are used. While there, ask to see slides of blood from a healthy person and from a person who had whooping cough, pneumonia, or some other germ disease. What differences do you see in the slides?

3. If you live near a milk-bottling company, visit it to see how milk is pasteurized.

4. Malaria, influenza, typhus, and typhoid fever are spread in various ways. Read about how these and other diseases spread. Look up the life history of the protozoan that causes the most common kind of malaria. Report to your class about the protozoan. Use drawings and diagrams to illustrate your report.

5. Paracelsus, Vesalius, and Paré were three great doctors in the Middle Ages. Find out what contributions they made to medical knowledge.

6. Measles, scarlet fever, and pneumonia are caused by different organisms. Ask your doctor or school nurse to tell the class about these organisms.

Man's Battle Against Disease

You have learned that microorganisms cause many diseases. Infectious diseases are caused by various microorganisms. Polio, mumps, and German measles are caused by viruses. Whooping cough and diphtheria are caused by bacteria. Protozoa (one-celled animals) cause diseases called **malaria** (muh-LAIR-ee-uh) and **dysentery** (DISS'n-tehr-ee). Ringworm, athlete's foot, and some other skin infections are caused by plants called fungi. These different kinds of disease-causing organisms are found everywhere. They are often found in your body. Yet you are healthy most of the time. How can you explain this?

Scientists have learned how to control many harmful organisms and thereby control infection. To do this, they must stop the growth of microorganisms. Our bodies have several natural defenses against disease. But when these natural defenses do not protect you and infections do occur, you are able to overcome them in several ways. Special drugs and medicines help destroy microorganisms in the body. Then you recover from the disease.

Great progress has been made in the continuous fight against disease, but there are still many health problems that need to be solved. The goal of medical scientists is someday to free mankind of disease. Let us see what scientists have learned about preventing disease.

Disinfectants Kill Germs

Hundreds of years ago, doctors had learned ways of curing some diseases. Surgeons performed many operations. However, every operation was a great risk. Most surgical wounds quickly became infected. Joseph Lister, an English surgeon, wondered why this happened. He also wanted to know how the infections could be stopped.

Lister had treated many patients with broken bones. Some had simple fractures. In a simple fracture the bones do not break through the skin. Others had compound fractures in which the bones did break through the skin. He noticed that simple fractures never became infected. Compound fractures almost always became infected. Why?

There was a noticeable difference between the two kinds of fractures. One kind opened the skin and exposed tissue to the air; the other kind did not. Pasteur had shown that bacteria were in the air. If Pasteur were right, bacteria in the air might be falling on open

Joseph Lister directs the use of carbolic spray in one of the earliest "antiseptic" operations.

wounds and causing infections. Lister formed the hypothesis that, if the air were free of bacteria, wounds would not become infected. How could air be **sterilized** (STEHR-uh-lyzd) — that is, made free from living microorganisms?

After much experimentation, Lister in 1867 found a chemical that destroyed bacteria in the air. He tested his hypothesis by spraying the air in the operating room with this chemical, **carbolic acid** (kahr-BOL-ik). Some of the chemical was also put on bandages that covered wounds. One after another, his patients recovered. There were very few cases of infection. Lister had learned to use a chemical to kill bacteria before they could cause infection.

Chemicals that are able to kill germs are called **disinfectants** (diss-in-FEK-tunts). Soap is a good example of a common disinfectant. When you scrub your skin with soap, tiny flakes of skin come off. Microorganisms on these flakes come off at the same time. Many other organisms that remain on your skin are killed by chemicals in the soap. In these ways soap helps to control microorganisms and reduce the danger of infection. Scrubbing with soap and water can help you avoid disease.

Other chemicals are also good disinfectants. Most home medicine cabinets contain bottles of alcohol, hydrogen peroxide, and iodine. These chemicals are also disinfectants.

How Do Some Chemicals Affect Microorganisms?

What You Will Need

ammonia
lysol
bleach
soap
1 quart of pond water containing protozoa
4 paper cups
medicine dropper
microscope
4 cover slides
4 glass slides

How You Can Find Out

1. Get a quart of pond water containing protozoa, or grow your own protozoa as you did before. See page 128 if you do not remember how to grow them.
2. Collect several household disinfectants such as ammonia, bleach, lysol, and soap.
3. Stir the pond water gently. Then pour an equal amount of the water into four paper cups.
4. Add a very small amount of soap to one cup, a few drops of bleach to the next cup, and so on. Put only one kind of disinfectant in each cup.
5. With the medicine dropper place a drop of water from each cup on a separate glass slide, cover the slides with cover slides, and examine the slides under a microscope. Be sure to rinse the dropper after each use.

Questions to Think About

1. What do you see when you look at the water with the microscope?
2. What chemical is in the bleach?
3. What effect does the soap have?

How Do Disinfectants Work?

What You Will Need

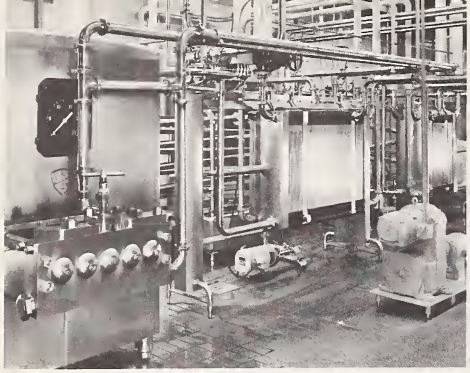
dried beans	4 test tubes	iodine
alcohol	lysol	sterile absorbent cotton

How You Can Find Out

1. Soak the beans in cold water for five or six hours.
2. Put several beans in each test tube and cover them with water.
3. Number the test tubes.
4. Do not add anything to test tube 1.
5. Add a little iodine to test tube 2.
6. Add a little alcohol to test tube 3.
7. Add a little lysol to test tube 4.
8. Stopper all the test tubes with sterile absorbent cotton, and put them in a warm place.

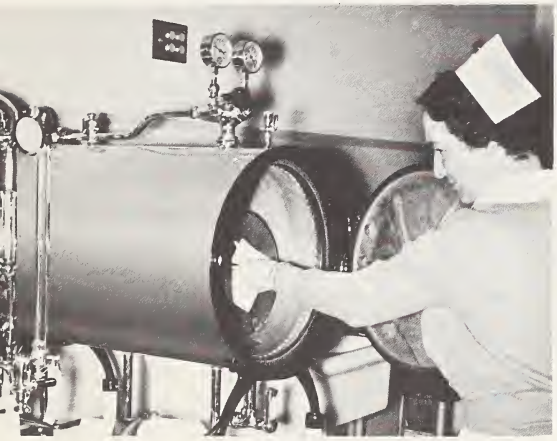
Questions to Think About

1. Remove the cotton and smell the contents of the test tubes. Do any of the test tubes have an odor?
2. What does the presence of an odor indicate?
3. How can you make certain that microorganisms cause the odor?



This equipment is used to pasteurize milk. Why is it unwise to drink untreated fresh milk?

What precautions are taken to make operations free from infectious microorganisms?



This instrument is called an *autoclave*. It sterilizes materials at very high temperatures.

Heat Kills Germs

Scientists have found that microorganisms can be destroyed by heat. Pasteur used heat to kill microorganisms in his wine experiment. Heat is also used to kill germs in many of the foods we eat. For example, to kill germs in milk, the milk is heated to about 160° F. for 15 seconds. At this temperature most microorganisms in the milk are destroyed. Then the milk is quickly chilled and kept cold until it is used.

The process of heating milk to kill bacteria is called pasteurization. Many foods, particularly canned goods and dairy products, are pasteurized or treated by other heat methods. In this

How Does Boiling Affect Microorganisms?

What You Will Need

1 quart of pond water containing protozoa	old pan	medicine dropper
	glass slides	microscope

How You Can Find Out

1. Use a quart of pond water or culture your own protozoa. Remember that you may have to wait four or five days before protozoa can be found in the culture.
2. Examine the culture or pond water under a microscope to make sure protozoa are present.
3. Stir the culture or pond water gently.
4. Pour one half of the pond water or culture into an old pan and bring it to a boil.
5. Let the liquid cool for an hour.
6. With the medicine dropper place a drop of the liquid on a glass slide. Cover it with a cover slide. Then examine with a microscope.

Questions to Think About

1. Do you see any protozoa on the slide?
2. Make several more slides of other samples of this solution. Are protozoa present?
3. Can you explain what happened?

way, harmful organisms in foods are killed before they enter the body.

You remember that Lister used chemical disinfectants to prevent infection. In hospitals today great care is taken to prevent the presence of infectious microorganisms. Operating rooms are kept **antiseptic** (an-tih-SEP-tik), as free of germs as possible. Surgical instruments are sterilized with steam at very high temperatures. Everyone who enters the operating room must scrub carefully and wear sterile clothing, masks, and rubber gloves.

EXPERIMENT

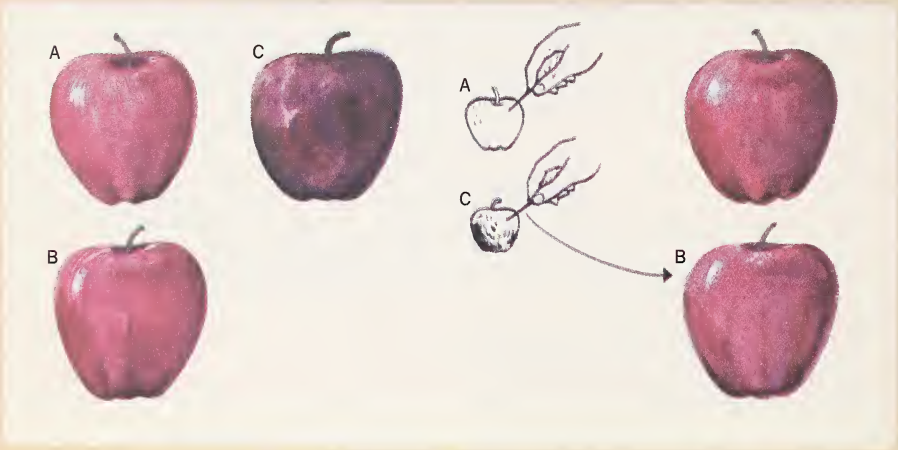
How Does an Infection Start, and How Can It Be Prevented?

What You Will Need

2 perfect apples
1 partly rotten apple
2 needles
alcohol

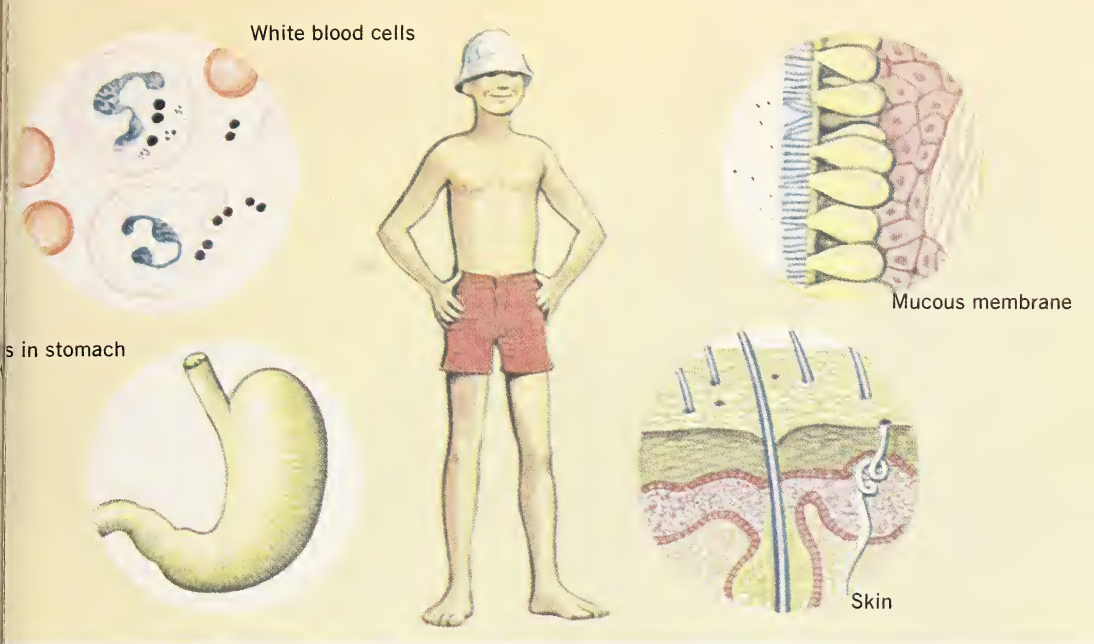
How You Can Find Out

1. Mark the perfect apples **A** and **B.**
2. Sterilize the two needles in alcohol.
3. Puncture apple **A** with one needle.
4. Puncture the rotten apple with the second needle and then inject apple **B** with this needle.
5. Keep apples **A** and **B** at room temperature for three to five days.



Questions to Think About

1. What happens to apple **A?**
2. What happens to apple **B?**
3. What have you found out about infection?
4. From what you have just seen, how do you think infection can be prevented?



THE BODY'S DEFENSES AGAINST DISEASE

Your Body Fights Germs

Your skin is your first line of defense against disease. Can you tell why? Harmful organisms that fall on the skin usually cannot get through it to cause infections. As you grow, tiny cells peel off the top layer of skin. The microorganisms peel off, too. Then new skin cells appear on the surface. In this way your skin acts as a barrier against disease.

You are also protected by the moist lining inside your nose and throat. This lining, the **mucous membrane** (MYOO-kuss), traps dust particles and microorganisms. When you cough or sneeze, many of them leave your body.

The digestive juices of the stomach also serve as protection. They contain acid, which kills many bacteria that you may swallow.

Even with these defenses, some harmful bacteria may remain alive in your body. When this occurs, the white cells of your blood may surround the bacteria and destroy them. Special substances in the blood help the white cells to do this. One of these substances attaches itself to each bacterium, and another causes the bacteria to come

together in clumps. The white blood cells can then destroy the bacteria more easily and quickly.

You are born with these defenses against bacterial disease. They are the body's natural defenses against disease.

Immunity to Disease

Some disease organisms, particularly viruses, are difficult to destroy. Since they grow and multiply inside living cells, the cells must be destroyed to kill the virus.

All of us have been ill with one or more virus diseases. Measles, mumps, and chicken pox are examples of virus infections. When you recover, you are **immune** (ih-MYOON) to these diseases. You remain immune for so long that you are not likely to get these diseases again.

However, there are some virus diseases, such as the common cold, to which you are immune for only a short time. When you are no longer immune, you may become ill with the same virus disease again.

Men have known about immunity for hundreds of years. From time to time, different diseases had attacked entire countries. Many people died, but some never caught certain of these fatal diseases. No one could explain why. Finally, experiments with one of these diseases provided the clue for a new way to provide protection against disease.

Long ago **smallpox** was a common disease. When it attacked, thousands died. Those who recovered were left with scars. Less than two hundred years ago, almost everyone carried the scars of smallpox.

To protect themselves from this dangerous sickness, people in China and Turkey purposely tried to give themselves mild smallpox infections. They hoped that they would be protected against a strong attack. It was a very risky treatment. Some survived, but many died of smallpox.

In England, milkmaids became ill with cowpox, a very mild disease of cows. When the milkmaids recovered, they did not get cowpox again. For some reason they did not get smallpox either. They became immune to both diseases.

This aroused the curiosity of Edward Jenner, an English doctor. He formed the hypothesis that cowpox and smallpox are alike in important ways. He believed that because of this those who recovered from cowpox also became immune to smallpox.

Jenner tested his hypothesis on May 14, 1796. First he collected some fluid

Dr. Edward Jenner gave his first vaccination on May 14, 1796. Today people in most parts of the world are vaccinated against smallpox.

from a cowpox blister. The fluid was injected into one of his patients, an eight-year-old boy. In a short time, the boy developed cowpox. But he recovered quickly. Jenner waited two months before going on with his experiment.

Now came the dangerous part of the test. Jenner injected the boy with smallpox. As Jenner expected, the boy did not get the disease. He was now **immunized** against smallpox. Jenner named this process **vaccination** (vak-suh-NAY-shun). Today, there are very few cases of smallpox in the world because people are vaccinated.

Following Jenner's discovery, scientists found ways of immunizing against other virus and bacterial diseases. One by one, new vaccines have been prepared. Today you can be immunized against diphtheria and polio as well as smallpox.

The English doctor's experiment was a landmark in medicine. It provided a new way to conquer disease. What would have happened to the boy if Jenner's hypothesis had proved wrong? The boy might have died of smallpox.

Experiments such as Jenner's are performed differently today. Research scientists working in laboratories try out experiments with animals before they are carried out with human beings.

Antibodies Provide Immunity

Vaccines help your body develop immunity to diseases. Immunity develops in a very special way.

When an organism enters your body, a new defense develops in your blood. As you fight off the infection, your body produces a special chemical substance. After a while, the substance makes the organism harmless. These special substances are called **antibodies** (AN-tih-bod-eez).

You produce antibodies for many kinds of disease-causing organisms. Some kinds of antibodies remain in the blood for a short time only. Others are

there for many years. A few stay with you for the rest of your life. As long as you have antibodies for a particular disease in your bloodstream, you are immune to that disease.

Jenner knew the technique for vaccinating against smallpox, but he did not understand *why* his patients became immune. Now you can understand the reason. The mild cowpox virus caused the body to produce antibodies against cowpox. These same antibodies are also effective against the smallpox virus.

Today's medical scientists build immunity in two ways. Killed microorganisms may be injected into your body. In this form they are harmless, but your body still produces antibodies for that disease. The Salk polio vaccine is a good example of a *killed virus vaccine*.

Another way is to inject certain *live* organisms. These organisms have been selected because they are very weak. They are too weak to make you sick. The antibodies are produced quickly. The Sabin polio vaccine is a *live virus vaccine*. Both types of vaccines make you immune to polio.

By knowing how to produce immunity, medical scientists have helped protect millions of people against many virus and bacterial diseases.

PATHFINDERS IN SCIENCE

Jonas E. Salk

(1914–) United States

During 1954, a million and a half American school children took part in an important scientific experiment. Some of these children were given shots of a cherry-colored vaccine that, it was hoped, would protect them from the crippling disease called polio.

The rest of the children, acting as a scientific control, were given shots of a harmless cherry-colored liquid. Neither the children, their parents, nor their doctors knew whether the children were getting vaccine or harmless liquid. Only the scientists conducting the experiment knew.

Careful records were kept of how many children in each group got polio. The two sets of records were compared with each other and with records of previous years. The records showed that the vaccine worked and was safe. Newspaper headlines and radio and television programs spread the news throughout the world—scientists had learned how to prevent the dread disease polio.

Hundreds of scientists worked many years to develop a vaccine to protect us from the crippling disease called polio. One man in particular, Dr. Jonas Salk, brought

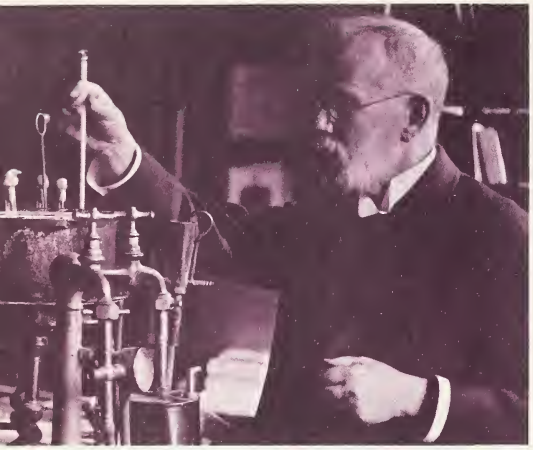
together many threads of polio research.

Great discoveries in any field are rarely, if ever, made by one man alone. Most often a discovery is the end product of years of thinking, exploring, observing, and experimenting. The results of all this work are published in scientific journals for all to read and accept or attempt to disprove. Often a researcher will use this knowledge in various ways.

About sixty years ago it was discovered that polio is caused by a virus. Scientists found that viruses could grow only in living organisms. It was only about twenty years ago that scientists discovered how to grow viruses in test tubes.

Dr. Salk looked for a vaccine that would kill the polio virus while it was in the bloodstream of a person. Such a vaccine, to be effective, would have to make the body produce enough antibodies to kill the polio virus before it could do any damage. Dr. Salk and his staff found that a vaccine that had polio virus in it worked. He and his staff found a vaccine that would kill the polio virus and at the same time would cause the body to produce antibodies, as the live virus does.

In 1954, when Dr. Salk was sure his vaccine was safe, he tried it on children. And in 1955, the world had a way to prevent polio.



Paul Ehrlich's research is an example of the way in which scientists test their ideas. He prepared 606 compounds to find Salvarsan.

Chemical Cures for Disease

Long before men discovered the causes of disease, they found remedies for several illnesses. Some of these remedies were plant products. For example, quinine is useful in treating malaria, a disease that may be caught in tropical countries. Quinine comes from the bark of cinchona trees.

When scientists discovered that bacteria cause disease, they started to search for other cures. Lister had shown that bacteria in the air could be killed by chemicals. But how do you kill bacteria *inside* the patient without harming the patient? Paul Ehrlich (EHR-lik), one of Koch's pupils, found a method.

Ehrlich had discovered how to color or stain bacteria so that they could easily be seen with a microscope. He used chemical dyes. Ehrlich knew that certain stains were absorbed by bacteria but not by normal body cells. He had experimented with a dye, trypan red, in the laboratory. This dye stains organisms that cause sleeping sickness. It also kills these organisms. Would this happen inside the body?

Ehrlich believed it would. After careful experiments with animals, he injected a patient with trypan red. The sleeping-sickness organisms were killed. The patient was unharmed. Ehrlich had discovered a chemical cure for a disease.

He set out to find other cures. Ehrlich, who was an expert chemist, prepared many arsenic compounds. Hundreds of these compounds were tested on infectious microorganisms. The 606th compound worked. It cured several diseases. In 1909, Ehrlich named compound 606 "Salvarsan," which means "safe arsenic." But too much arsenic is poisonous, and not every doctor used Salvarsan properly. Salvarsan was an effective cure for some diseases; but when it was not used wisely, the patient sometimes died.

Years later scientists discovered safer chemicals that are able to cure diseases.

Sulfa drugs are a good example. Many kinds of sulfa drugs were produced. Each type of drug worked well against specific kinds of bacteria. For some years sulfa drugs were the best chemical cures for bacterial infections, but soon better cures were found. They were far more powerful than sulfa. They have often been called the "wonder drugs." You know them as **antibiotics** (an-tih-by-OT-ikss). An antibiotic is a substance, produced by a living organism such as a bacterium, mold, or fungus, that fights germs.

Antibiotics Fight Disease

Most great medical discoveries result from careful experimentation. Antibiotics were not discovered in this manner. They were discovered by accident. A British scientist, Alexander Fleming, had been studying a common type of bacteria. Pure cultures of the bacteria were growing in nutrient agar plates. One morning in 1929 Fleming found that for some reason the bacteria on some of his culture plates had been destroyed.

Fleming examined the plates carefully to discover the reason. What he found surprised him. He discovered that the bacteria had been killed by a common green mold.

Fleming believed that some "something" made by the mold *Penicillium* had killed the germs. He called the "something" **penicillin** (pen-uh-SIL-in). He wrote a report about this discovery,

Alexander Fleming examines penicillin cultures. On the right is the mold *Penicillium chrysogenum*, a form of penicillium that produces almost all the world's penicillin.

but no one seemed interested at the time. Fleming forgot about it, too! In 1938, two British scientists, Howard W. Florey and Ernest Chain, raised this same green mold in a laboratory. One of the substances from the mold was deadly against certain bacteria.

Penicillin was carefully tested on animals. When research scientists were as sure of its safety as they could be from extensive testing results, penicillin was used on human beings.

Penicillin became a powerful new weapon against disease. It can kill many kinds of bacteria, and it works quickly. For most people, penicillin is indeed a wonder drug.

But some people get *side effects,* such as hives, from using penicillin. Also, penicillin is not effective against all bacteria.

Scientists searched for other antibiotics without these difficulties. Many new antibiotics have been developed. Some of them come from soil molds. Some types of bacteria that penicillin does not kill are killed by some of these new antibiotics. Find the names of some of these new antibiotics and the diseases that the antibiotics are used to treat.

Sometimes antibiotics upset the normal balance of microorganisms in the body. Many types of bacteria and fungi are usually present in everyone. These microorganisms are necessary for good health. When antibiotics are used to kill harmful bacteria, many useful bacteria are killed as well. As a result, fungi may multiply much more rapidly than they normally do. Then you may develop a fungus infection which can also make you sick. In a few days, however, the helpful bacteria multiply and the balance of microorganisms is normal again.

Antibiotics have saved the lives of millions of people. But the widespread use of them has created another difficult problem. After a time, a particular antibiotic may no longer work against certain bacteria. At first, scientists could not understand why this happened, but now they believe they can explain it.

Most offspring of bacteria are exactly like the original cells. But occasionally an offspring is not altogether like others of its own kind. It is called a **mutant** (MYOO-tunt). Mutant bacteria may adjust differently to conditions around them. For example, a mutant organism may not be affected by the chemicals that affect other bacteria of the same kind. When this mutant organism multiplies, more of the same are formed.

Scientists are discovering new antibiotics very rapidly. Can you name any antibiotics that you have taken? What disease did they help cure?

Ordinary bacteria will be killed by an antibiotic. But there are some mutants that cannot be killed by the antibiotic. They continue to multiply in spite of the presence of the drug. A new **strain** of bacteria is formed. Its main characteristic is that it is **resistant** to that particular antibiotic. The new strain may now be passed on to another person. Often these new resistant strains are more dangerous than the original disease organism.

This problem is being solved by the continual discovery of antibiotics that are effective against new strains of microorganisms. As long as resistant strains appear, new antibiotics will be needed to control infectious diseases.

You have learned something about infectious diseases. But there are many diseases that are not infectious. This means that they are not caused by germs. These noninfectious diseases, some of which you will read about below, have other kinds of causes.

Noninfectious Diseases

Do you have hay fever or rose fever? Do you start to sneeze when you are near a cat or a dog? If so, you have an **allergy** (AL-er-jee). Some people break out in hives after eating strawberries. Others develop itching after eating eggs. A person who is sensitive to a specific substance is said to be **allergic.** Allergies are a form of disease.

Are any pupils in your class allergic to certain substances? How do they react to these substances?

Some people suffer from deficiency diseases. These diseases are caused by a lack of necessary food elements. For example, **scurvy** (SKER-vee) is a deficiency disease caused by a lack of vitamin C. If you drink orange juice and other citrus juices, you will not get scurvy.

You may have heard of people who suffer from diabetes or goiter. These diseases are caused by disturbances in production of hormones in the glands.

There are also diseases that are caused by harmful habits, such as the drinking of great amounts of alcoholic beverages or the excessive use of certain drugs.

People who constantly drink great amounts of alcoholic beverages are called alcoholics. They suffer from the disease called alcoholism.

Some people, called drug **addicts** (AD-ikts), misuse certain drugs and develop the habit of taking drugs regularly.

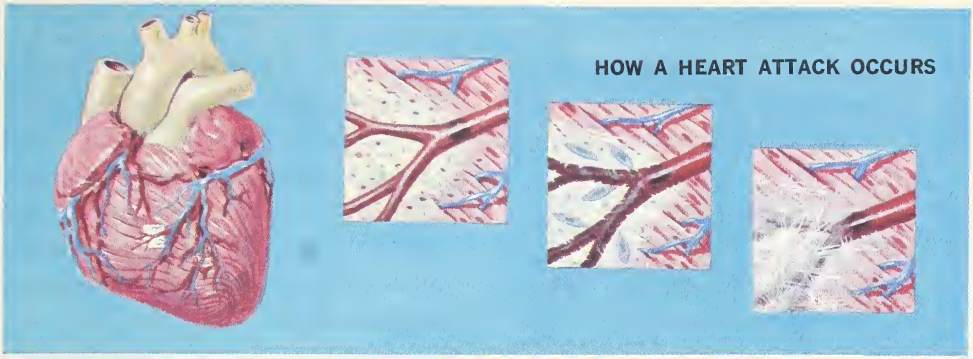
In 1964, the United States Surgeon General's report stated that smoking is closely linked to lung cancer and respiratory and other diseases. Thus smoking must now be included among the causes of disease.

At the beginning of this unit, we talked about degenerative diseases. These diseases result from the wearing out of such organs or systems as the heart and blood vessels, the kidneys, the nervous system, and the liver. Some of these diseases are partly the result of heredity and aging. Others are the result of infectious disease and poor personal hygiene.

Two of the most serious health problems in the United States are **heart disease** and **cancer.**

The heart may become diseased in several different ways. Occasionally the heart does not develop in a normal way before birth. For example, the heart wall between the lower chambers sometimes has an opening that does not belong there. The blood cannot circulate properly because of this opening. Surgeons can sometimes repair this kind of defect inside the heart. If the opening is small, a flap of muscle tissue may be sewed over the hole. A larger opening can be closed by stitching a plastic plug into the defect. Surgery can be used to correct several kinds of heart defects.

Another cause of heart disease is **rheumatic fever** (roo-MAT-ik). If rheumatic fever, which starts as a streptococcus throat infection, is not treated properly with antibiotics, the muscles



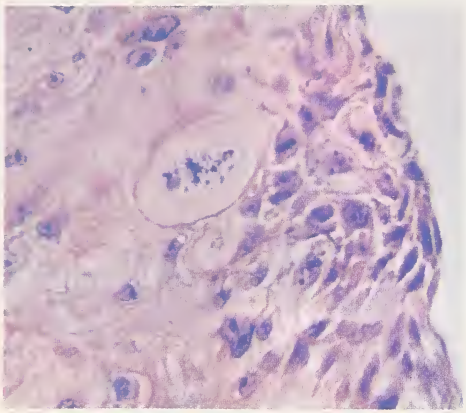
Sometimes trouble develops in one of the blood vessels of the heart. When an artery of the heart is blocked by a clot, the muscle fibers begin to fall apart. White blood cells ingest the dead tissue. After 5 or 6 weeks, other cells begin producing connective scar fibers. After about 3 months, a scar is formed. Why is it important that a scar forms?

and valves of the heart may become inflamed. This inflammation may also affect the arm and leg joints. A lengthy stay in bed is then necessary until the inflammation is cured. The physician tries to treat rheumatic fever so that rheumatic heart disease does not develop.

The most common type of heart disease occurs mainly in older adults. It involves the thickening of the inside lining of the small "coronary" arteries. These arteries supply blood to the muscles of the heart. This thickening of the lining of the arteries is called **arteriosclerosis** (ahr-TEER-ee-oh-skler-OH-siss). If the blood flows too slowly through the narrowed artery, a clot may form and the flow of blood will be blocked. Then the nearby muscle receives no oxygen. This causes a heart attack, or coronary attack. Doctors believe that arteriosclerosis is more common in those adults who smoke and in those whose diets contain a great deal of animal fat than in other people.

Physicians are learning new ways to prevent and cure heart disease. But it remains one of our most important health problems.

Cancer is another serious health problem. Most cases occur in middle and old age. Cancer can start in any organ of the body. Some of the cells of a certain organ grow out of control. Their rapid and wild growth forms a **tumor.** The enlarged tumor destroys the normal cells that are near it and interferes with the work of the organ. Such rapidly growing cells may spread and affect other areas of the body.



Cancer cells grow out of control, destroying normal cells and interfering with the work of the organ they are growing in or near. Below you see a patient being given radiation treatments to arrest and possibly cure cancer.

Doctors have had some success in treating cancer. Surgery can be used to treat certain forms of the disease if the cancer is discovered before it has spread too far. The surgeon can remove the diseased tissue. But surgeons cannot positively tell whether or not the patient is cured. They must check the patient periodically for several years to make sure they removed all the cancer.

Some cancers are treated by **radiation** (ray-dee-AY-shun). Powerful rays are beamed at the cancer. The radiation may destroy the cancer cells, or it may slow down their growth for a while.

Why have we not discovered how to cure cancer? The real reason is that we do not know the cause of the disease. Scientists have developed a number of hypotheses. Some believe it is caused by viruses. They consider cancer an infectious disease. Others believe that certain irritating chemicals cause cancer. We take in many chemicals with food, water, and air. Do some of these chemicals cause human cancers? People who smoke cigarettes are much more likely to get a particular type of cancer than those who do not smoke. Many doctors believe that there is some chemical in cigarette smoke which causes cancer. They advise people to give up the cigarette-smoking habit or not to begin smoking at all.

Perhaps cancer is really several diseases with a number of causes. Some day scientists hope to find out.

The Battle Against Disease Goes On

Scientists have always battled to conquer disease. They have identified many of the organisms that make you sick. Ways of fighting infectious diseases with chemicals and antibiotics have been found. Vaccines have been developed to help you build immunity to many diseases. Today surgery does not involve the risk it did in former times. Today most of us can look forward to good health and a long life.

By evaluating evidence and testing ideas carefully, scientists have found the causes of and cures for many diseases. But some others are still mysteries. Many scientists are working to conquer these diseases. Some seek the causes, while others search for better ways to treat and cure diseases. Slowly, new evidence is being found. Another approach to the conquest of disease is a better understanding of the human organism. What characteristics does one person have that make him more likely to become sick? Why are some people hardly ever sick? Is there something different about their bodies that makes them resist harmful microorganisms? Why do many people in some families have diabetes? Why are some people allergic to ragweed while others are not? Why do cells begin to grow out of control? Scientists are trying to find the answers to all of these questions.

Man's battle against disease goes on. Someday mankind may be free of diseases. When will that day come? Nobody knows. Scientists are working toward that goal. Perhaps you will become a scientist, add to scientists' knowledge, and reduce the time it takes to reach the goal of a world free from disease.

Scientists battle disease on many fronts. New drugs are tested on animals before they are used on human beings.

To discover disease in its early stages, medical scientists use trucks carrying X-ray equipment to test people for chest diseases.

The medical ship "Hope" treats people in parts of the world where there are no or very few doctors.

Fighting and preventing disease is also the work of members of the Food and Drug Administration. They inspect sanitary conditions in food processing plants, make "control" inspections of drug manufacturers, and so on.

Using What You Have Learned

1. Test the effects of penicillin on a potato culture. You know how to make a potato culture. Prepare at least four cultures for your experiment. Ask your doctor or druggist for a penicillin tablet. When growths appear on the potatoes, crumble the tablet in a few drops of water. Soak small pieces of paper toweling in the penicillin. Place them on two potato slices. Cover the potatoes again and place them in a warm, dark place for several days. Then observe the cultures. Look closely under the penicillin-soaked paper and around the edges. Is there any difference between the cultures with penicillin and the untreated cultures? Were any organisms affected?

2. Test other antibiotics as you did penicillin and compare the results. A few samples of other drugs are all you need. Your doctor or school nurse might be able to get them for your experiment.

3. Read about a world-wide program to conquer disease. Write to the World Health Organization, United Nations, New York, N.Y., for booklets and other material.

4. Follow the current newspapers and magazines for new discoveries about the causes and treatments of diseases.

5. What is done by your community to protect you against dangerous diseases?

6. How are antibiotics tested to see which organisms they can destroy? Ask your family doctor to obtain antibiotic test rings for you. Ask him how they are used in laboratories.

7. Now that you have read this unit, can you tell why it took mankind so long to find out what the causes of most germ diseases are?

WHAT YOU KNOW ABOUT

Conquering Disease

What You Have Learned

Diseases have many causes. There are **deficiency diseases, infectious diseases,** and **degenerative diseases.**

Long ago, people thought there were four liquid **humors** in the body. They believed that people were in good health if the humors were balanced. Scientists later discovered that microscopic organisms, which they called **microorganisms,** live in the body. This led to the **germ theory of disease.**

To help scientists find the bacteria that cause diseases, Robert Koch developed a set of rules based on certain assumptions:

1. The organism must be seen in every case of the disease.
2. The organism must be grown in a pure culture.
3. Injected organisms obtained from a pure culture must cause the disease in a healthy animal.
4. The organism must be found in the infected animal and grown again in a pure culture.

Scientists later found that some diseases were caused by **viruses,** not by bacteria. Today great advances are being made to conquer disease.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

addict	antibodies	mutant	strain
allergy	disinfectants	radiation	vaccination
antibiotics	immunity	spores	virus

Which Is It?

Below are four diseases. Write them in your notebook and next to each one tell whether it is an infectious, degenerative, or deficiency disease.

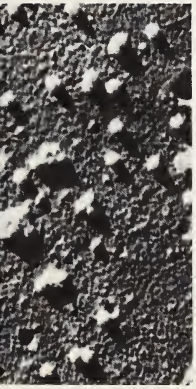
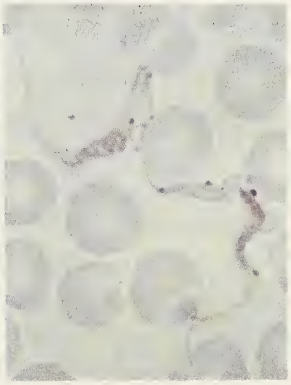
measles
scurvy
whooping cough
arteriosclerosis

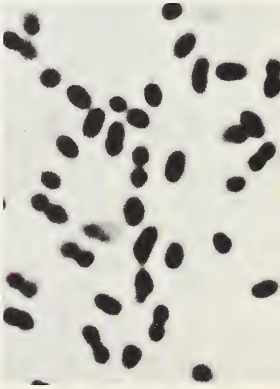
Tell the Difference

1. antiseptic—disinfectant
2. antibody—antibiotic
3. pasteurization—sterilization
4. vaccination—immunization
5. culture—colony
6. bacterium—virus

Do You Know?

Name three diseases caused by viruses.
Name two diseases caused by protozoa.
Name two diseases caused by fungi.
Name two diseases caused by bacteria.



YOU CAN LEARN MORE ABOUT

Conquering Disease

Match the Scientists

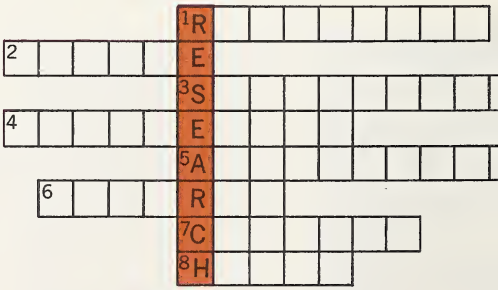
Can you match the names of the scientists with the words at the right?

1. Paul Ehrlich	anthrax
2. Alexander Fleming	sterilization
3. Edward Jenner	pasteurization
4. Robert Koch	penicillin
5. Joseph Lister	Salvarsan
6. Louis Pasteur	vaccination

What Are the Words?

Each letter in the word on the right is also a letter in a science word that you have learned in this unit. Find a word for each letter without using the same word more than once. Study the clues below for the words to use.

1. A method of treating cancer.
2. Protected against getting a disease.
3. Destroys bacteria.
4. Free from germs.
5. A substance produced by a living organism that fights germs.
6. A sensitivity to a specific substance.
7. The growth of bacteria on a specially prepared substance.
8. The organ concerned in one of the United States' most serious health problems.



You Can Visit

Perhaps your class will be able to visit a drug company. Here you will see how drugs are made and packaged. You may also have a chance to visit the laboratories where scientists are at work trying to find the causes and cures of many diseases. Ask the tour guide how long a drug must be tested before it can be sold.

You Can Read

1. *The Wonderful World of Medicine,* by Ritchie Calder. Tells about man's search for knowledge about himself and the ways to combat his diseases.
2. *Modern Medical Discoveries,* by Irmengarde Eberle. Tells how life-saving medicines such as penicillin were discovered and how they prevent the spread of disease.
3. *Walter Reed : Vanquishing Yellow Fever,* by Edward F. Dolan, Jr. How Walter Reed wiped out yellow fever.
4. *Polio Pioneers: The Story of the Fight Against Polio,* by Dorothy and Philip Sterling. The history of the disease and those who fought it.
5. *Master Surgeon: A Biography of Joseph Lister,* by Laurence Farmer. Lister's efforts to eliminate sources of infection.

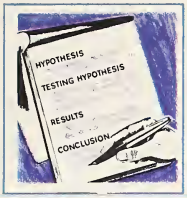
Do You Remember?

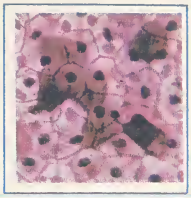
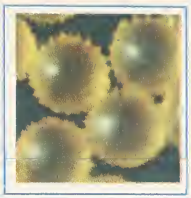
Scientists solve problems by putting them in the form of questions and developing *hypotheses* that are possible answers to these questions. A hypothesis must be tested many times to see if it is really the answer to a question. After a hypothesis is tested many times by many scientists and the same results are obtained, the hypothesis becomes a statement of fact. A *theory* tries to explain the facts that have been discovered. Theories may change as more hypotheses are tested and scientists add to their store of knowledge.

Probability theory is a theory about hypotheses themselves. It deals with how probable it is that any event will occur. Many hypotheses are so highly probable that they are accepted as being true. Scientists keep records to help others to repeat their work, to form theories, and to determine probabilities.

The *cell theory*, which says that all living things are made up of *cells* or of cells and their products, has a very high degree of probability. Scientists have studied many kinds of living things and found them to be made up of cells. All cells contain a *nucleus* surrounded by *cytoplasm*. The cytoplasm is surrounded by a *cell membrane*. In plant cells, the cell membrane is surrounded by a *cell wall*. Groups of similar cells make up tissues. Tissues work together to make up organs. Organs work together to make up systems of the body. All living things are *organized living systems* called *organisms*.

Every living thing begins as a single cell. Most animals begin as an *egg cell* that is *fertilized* by a *sperm cell*. The development of plants is similar to that of animals. *Embryology* is the study of the early development of living things. All living things need



certain materials provided by food to develop from a single cell to adulthood. The *rate of growth* varies throughout the lifetime of a living thing and is different for each living thing.

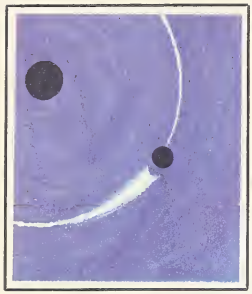
Your systems work together to keep you healthy. The digestive system turns the food that you eat into material your cells can use. The *blood* carries food to your cells and wastes away from your cells. Your *heart* pumps blood to your *arteries*. The blood goes from the arteries to *capillaries* and back to the heart through *veins*. Your *respiratory system* provides oxygen for your needs. You get rid of wastes through your *excretory system*. Every move you make requires the smooth working of your *bones* and *muscles*. Your *nervous system* helps all your systems adjust to change. Your nervous system and your *glands* also keep certain of your body's activities going automatically.

When your systems are not working properly, you have a disease. There are *deficiency, infectious,* and *degenerative diseases*. The first line of defense against infectious disease is your skin. Another defense is the *mucous membrane* lining your nose and throat, which traps dust particles and *microorganisms*. *Germs* that you swallow may be killed by acid in the digestive juices in your stomach. If any germs get beyond these defenses, the white cells of your blood may surround the germs and destroy them. Today we know that germs cause some diseases and *viruses* cause other diseases, but we still do not know the causes of many diseases. We can control or cure certain diseases with *disinfectants,* heat, *immunization,* chemicals, surgery, and *radiation*. But the fight against disease continues.

6

The World of Chemistry

The Chemist and His Work
Observing Crystals
Elements, Atoms, and Molecules



As you learned, living things are the subject of biology. Biologists learn much by studying the cell—the basic unit of life. What everything is made of is the subject of chemistry. Chemists learn much by studying the atom—the basic unit of all matter. You will now read about the chemist and his work.

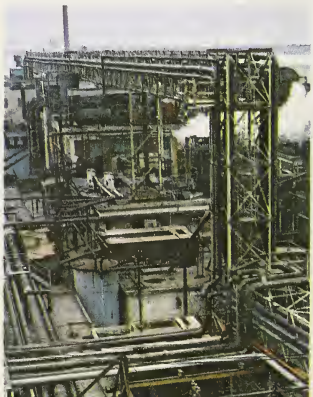
The Chemist and His Work

There is a rainbow of colors in your classroom. Look at the clothes your classmates are wearing. How many colors do you see? When your grandparents were in school, they did not wear clothes of all these colors. Most of their clothes were dyed black or blue.

Are you wearing something made of nylon, dacron, or rayon? If not, you probably have something at home made of one of these fabrics. Just thirty years ago, these fabrics did not exist.

In recent years chemists have made dyes, fabrics, and many other kinds of things of substances not combined in nature in the ways chemists combine them. Chemists study all substances. They want to know what the various substances are made of, how one substance is different from another, and how the substances interact. As chemists find out more about natural substances, they look for ways to produce new substances, such as plastics.

The materials on the left are fabrics made by scientists from various chemicals. The pipes in the factory on the right are made of various kinds of plastics.



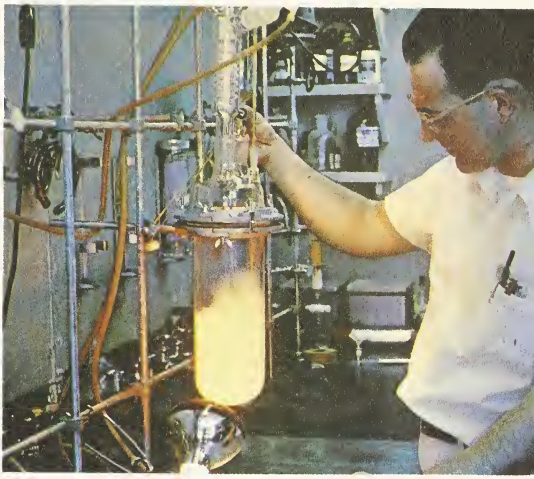
Chemists all over the world are searching for new chemical facts. The basic ideas of chemistry guide them in their search. You, too, can learn some of these basic ideas. When you learn some facts about crystals, solids, and liquids and about atoms and molecules, you will be able to see the world in some ways as the chemist sees it.

Observing and Describing Substances

As you walk along a road or through an open field, you may see weeds and flowering plants, birds and insects, sand and rocks. Some of the things you see are large; others are small. Some are colored; others are colorless. You can tell something about each thing that you see.

All your life you have been using words to describe objects. You know what these objects look like and how they act. You have tried to explain what they are and what they are made of. By observing and describing, you have been acting in the same way as a chemist acts.

A chemist spends much of his time observing and describing. A chemist must observe and describe substances very carefully to classify them and divide them into groups for further study and use. A chemist also describes things in special ways.



A researcher prepares a new synthetic chemical that will be tested as a mental-health drug.

A chemist begins a description of a substance by listing its **properties** (PROP-er-teez), or its special characteristics. A substance has **physical properties** and **chemical properties.**

Physical Properties

What are the physical properties of a substance? You might begin your study of a substance by asking questions such as: What does it look like? What is its color? What is its shape? How does it taste? What does it smell like? Color, shape, taste, and odor are physical properties. Physical properties are those that can be observed without the substance changing into something else.

You already know many physical properties of many things. For example, you know that grass is green, a lemon is sour, and a rose is red. But a chemist must be more exact in his descriptions. A chemist must be exact about the color of an object because there are many shades of colors. He must be exact about taste because some things are sweet and others are sweeter. As a result, a chemist describes physical properties in greater detail than you do. He also describes certain properties you probably do not describe. One of these properties is the **state of matter** of a substance. As you have learned already, matter is anything that takes up space.

These researchers are testing various things to find out their physical properties. What do you see them doing in the picture?

PATHFINDERS IN SCIENCE

Antoine Laurent Lavoisier

(1743–1794) French

As a young man, Antoine Lavoisier (lah-vwah-zee-AY) studied law, because his father was a successful lawyer. But Lavoisier, instead of practicing law after receiving his degree, began to do research in many areas of science. He was so successful that at the age of twenty-five he was elected to the French Academy of Sciences.

Before Lavoisier did his research, chemists believed that when a material burns, it gives off a substance called *phlogiston.* They thought, moreover, that phlogiston is the substance that actually makes material burn.

Lavoisier experimented with tin. When he burned tin, he found that the ash that resulted weighed more than the tin had weighed before it had been burned. He was puzzled. How could the ashes weigh more if phlogiston was given off by burning? Shouldn't the ash weigh less?

Next, Lavoisier experimented with phosphorus. Again, the ash that resulted from burning weighed more than the original amount of the substance. Experimenting with sulfur, Lavoisier captured the gases given off by burning sulfur. He weighed these gases and found that they also

weighed more than the original amount of sulfur. Lavoisier reasoned that when a material burns, it does not give off a substance —instead, it combines with air. He believed, for example, that during the burning of sulfur, oxygen from the air combines with sulfur to produce the gases. Thus the gases weigh more than the sulfur did before burning.

Joseph Priestley, an outstanding English scientist, had made what he called "dephlogisticated air," or air without phlogiston in it. Lavoisier called this air *oxygen.* He set about to show that when a material burns, it combines with oxygen. After many experiments, Lavoisier upset the theory of the giving off of phlogiston by a burning substance. Lavoisier claimed instead that *when something burns it combines with oxygen.*

One of Lavoisier's great contributions was to simplify chemical terminology. He was bothered that the names for chemical substances—compounds and elements—did not follow an orderly pattern. Lavoisier noted that names in chemistry very rarely had any connection with the things or processes that they named.

Lavoisier developed terminology still used today to name the elements. And he contributed the "shorthand" of chemistry: instead of using hundreds of words to describe the chemical reaction in fermentation, for example, Lavoisier would write:

Fermentation → alcohol + acid + oxygen

Lavoisier was a genius who pioneered in other areas as well as chemistry. He urged new agricultural methods, suggested tax reforms, headed an institution that later became the Bank of France, and devised still other economic reforms. His abilities in both science and business made him a valuable advisor to the government.

Lavoisier is called the father of modern chemistry, for he succeeded in demonstrating the importance of chemistry, stimulating the imaginations of chemists, and interesting them in research.

DEMONSTRATION

How Does the Chemist Describe Things?

What You Will Need

balance scale ruler block of wood

How You Can Find Out

1. Try to guess the length, width, and thickness of the wood block.
2. Try to guess the weight of the wood block.
3. Then use the ruler to measure the length, width, and thickness of the block of wood.
4. Use the balance scale to find the exact weight of the block.

Questions to Think About

1. How do your guesses about the measurements of the wood compare with the measurements which you made with the ruler?
2. How does your guess about the weight of the wood compare with its weight as measured by the balance scale?
3. How do ordinary methods of observing compare with the chemist's methods?

States of Matter

Examine the cover of this book. Compare it with some water running from a tap. Compare the book cover and the water with the air around you. In what major way do these three things differ?

You can see that the book cover is a **solid,** the water is a **liquid,** and the air is a **gas.** Each of the substances is in a different state of matter. The three states are: solid, liquid, and gas. Every substance known is in one of these three states of matter.

Usually it is easy to decide what state of matter something is in. A solid substance has a definite shape. A rock keeps its shape in any kind of container. A rock is a solid. A liquid takes the shape of the container into which

it is put, but it remains at the bottom of the container. Alcohol and vinegar are liquids. A gas completely fills its container. Air is a gas. The air in your classroom fills every part of the room.

Changes of State

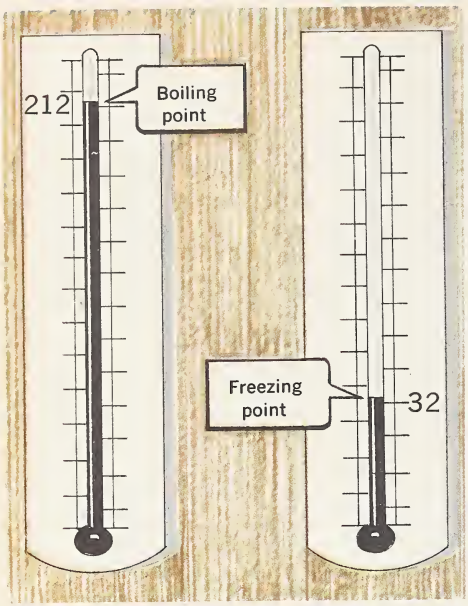
Some substances can change from one state to another. You have seen water change to a solid, called ice. Ice can change to a liquid, called water. Water can change to a gas, water vapor.

As liquid water becomes a solid or a gas, it changes from one state to another. An object sometimes changes from one state of matter to another when its temperature changes. The temperature at which such a change takes place is an important physical property. That is why chemists often use temperatures at which changes of state occur to describe substances.

Substances can be changed from one state to another by adding heat or taking away heat. When heat is used to change a solid into a liquid, we call the process melting. All substances that melt do so at a fixed temperature. This temperature is known as the **melting point** of the substances. Ice has a melting point of 32° Fahrenheit. The point at which water freezes is also 32° F. We call this temperature the **freezing point** of water. What do the processes of freezing and melting have to do with each other?

Chemists also use the **boiling point** to describe a substance. Water boils at 212° F. at sea level. Make a list of the boiling points of various substances, such as ethyl alcohol, ether, and gasoline. You can find these boiling points in the *Handbook of Chemistry and Physics*. (You will need to use the index of this thick reference book.)

Can you tell and describe the state of matter of each of the materials in the jars?



How do the boiling and melting points of a substance help the scientist to identify it?

Not all substances melt or boil easily. For example, it takes a tremendous amount of heat to make solid iron into iron gas. Solid iron becomes a liquid at 1795° F., and liquid iron changes to a gas at 5432° F. Also, a tremendous amount of heat must be taken from oxygen gas to change it into a liquid. Oxygen gas becomes a liquid at −297° F., which is a reading that is far *below zero*.

Such temperatures are not easy to get. But there are many changes of state that you can produce. These other changes of state do not need so much heat or cold. Sulfur is a solid at room temperature. You can easily change the state of sulfur. Heat a *small* amount of sulfur (about one-quarter teaspoonful) in a test tube. What happens when you heat the sulfur?

Solubility of Substances

Some substances dissolve readily in water. Other substances do not dissolve in water. If a substance dissolves in water, it is **soluble** (SOL-yoo-b'l) in water. An important physical property of any substance is whether it dissolves in another substance. This property is called **solubility.**

Here is a way to learn more about solubility. Put one teaspoonful of salt into a half cup of water. Stir the water. What happens to the salt? What kind of substance is salt? Then put one teaspoonful of sugar into another half cup of water. Now stir the water. What happens to the sugar? What kind of substance is sugar?

Now try putting one teaspoonful of calcium carbonate (chalk) into one-half cup of water. Stir the water. What can you say about the solubility of calcium carbonate in water compared with the solubility of salt and sugar in water?

Do Substances Always Change from Solid to Liquid to Gas?

What You Will Need

large test tube
test-tube holder
burner
moth ball
pan of water
stand to hold the pan

How You Can Find Out

1. Place the pan of water on the stand.
2. Use the burner to heat the water to the boiling point.
3. Place one moth ball in the test tube.
4. Using the test-tube holder, place the test tube in the hot water for about two minutes.
5. Watch what happens to the moth ball.
6. Hold the test tube in the hot water for about two more minutes. Observe what happens.

Questions to Think About

1. Does anything unusual happen to the moth ball?
2. Do you see the usual changes in state?
3. What is the special name given to this process? How can you find it?

You can do another experiment in solubility. Put one level teaspoonful of table salt into one-quarter cup (2 ounces) of water. Stir until the salt dissolves completely. Will the water dissolve more salt? You can see. Add another level teaspoonful. Stir the water. Keep adding measured teaspoonfuls of salt. What do you observe about the solubility of salt in water as more and more salt is added?

When a substance dissolves in a liquid, a **solution** (suh-LOO-shun) forms. In the experiment which you have just done, you made a solution of salt water. The process of forming a solution may be shown this way:

$$\text{salt} + \text{water} \longrightarrow \text{salt solution}$$

When you have added a certain amount of salt to the water, you reach a point at which no more salt will dissolve. You then have a **saturated** solution. When you have a saturated solution, some of the salt in solution comes out of the solution and forms solid salt again. This process is usually too fast to see. The particles that form are very small and are invisible. This process is always going on in a saturated solution. It is shown this way:

$$\text{salt} + \text{water} \rightleftharpoons \text{salt solution}$$

Notice that a *reverse* process is occurring. Some of the salt is dissolving while some of the salt is becoming a solid. Both these things are happening at the same time. The lengths of the arrows show the relative speeds of the two processes. In a saturated solution, the salt is dissolving in the water as fast as the dissolved salt is changing back to a solid. If you keep adding salt to a certain amount of water, you soon reach the point where no more salt dissolves.

A comparison can now be made. Start with one-quarter cup of water. Add small, measured amounts of sugar. See how much sugar you must add before you have a saturated solution, or before the solution is balanced. A balance is reached when no more sugar dissolves. How much sugar is needed to saturate one-quarter cup of water? How much salt is needed to saturate one-quarter cup of water?

Solubility and Temperature

Make a saturated salt solution. At room temperature, about four teaspoonfuls of salt in a quarter cup of water make a saturated solution. You can be sure it is saturated by adding another quarter teaspoonful of salt. Stir. If the additional salt does not dissolve, then the solution is saturated.

What safety precautions should you follow when doing this experiment?

Now heat the solution, but do not allow it to boil. Does some of the additional salt dissolve? What can you say about the effect of heat on solubility?

Compare the effect of heat on a salt solution with the effect of heat on a hypo solution. Hypo is a chemical often used to make pictures from films. You can get some hypo from a photographic supply store.

About eleven teaspoonfuls of hypo in one-quarter cup of water make a saturated solution at room temperature. Try heating a saturated solution. Do not allow the solution to boil. Add small amounts of additional hypo. Notice how many more teaspoonfuls can be dissolved as you heat the solution. Compare this amount with the additional salt that was dissolved when you heated the salt solution. Do you find that the solubility of some substances increases greatly as you heat them? The solubility of some other substances increases only a little when you heat them.

The solubility of a substance at different temperatures is an important property of the substance. Often, chemists must know at what temperature a substance will dissolve in order to decide whether to use it for a certain job. The solubility of substances is affected by temperature changes. The solubility of some substances increases as the temperature rises. The solubility of other substances decreases.

EXPERIMENT

How Does the Solubility of Gases Change?

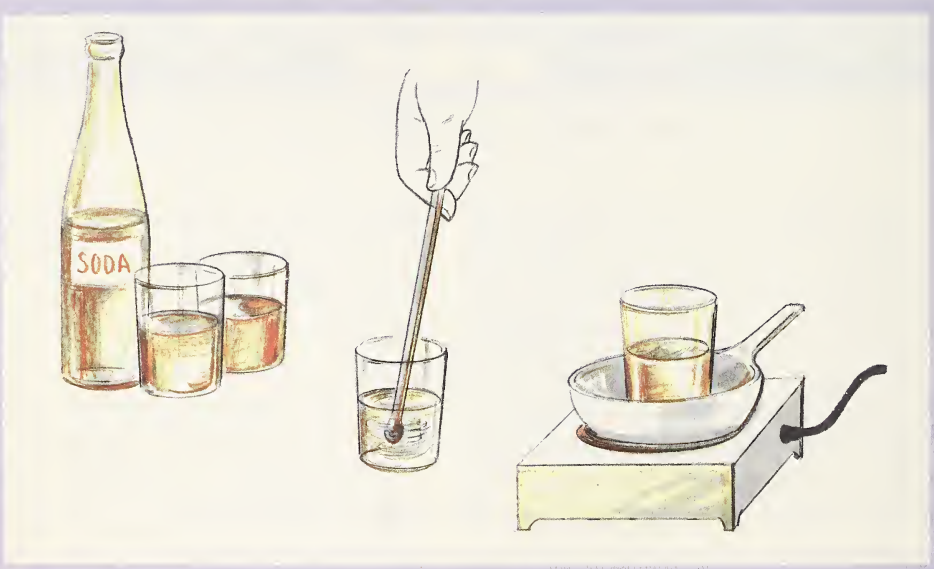
What You Will Need

1 cold bottle of soda 2 heat-resistant glasses

source of heat

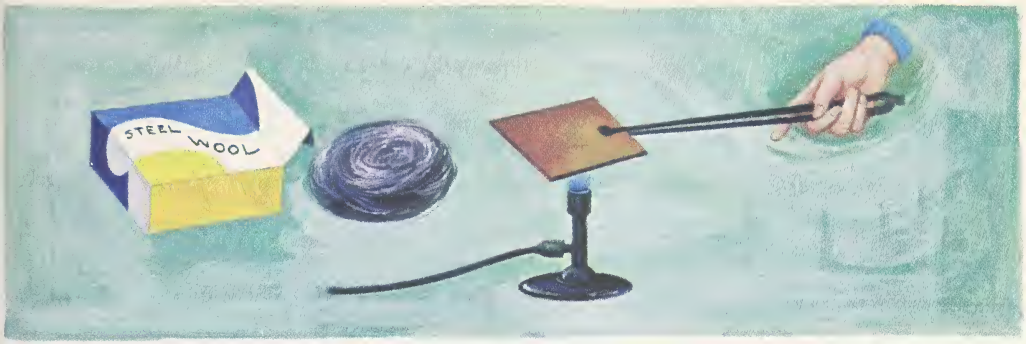
How You Can Find Out

1. Fill both glasses about halfway with soda.
2. Stir the soda in one glass slowly at first, and then stir it faster.
3. Slowly heat the second glass of soda.



Questions to Think About

1. Carbon dioxide, a gas, is dissolved in water to make soda. How does stirring change the solubility of gases in water?
2. How does heating change the solubility of gases in water?
3. Is there any difference in the way that heat changes the solubility of gases and solids in water?
4. Is there any difference in the way that stirring changes the solubility of gases and solids in water?



Chemical Properties

To better understand the work of chemists, one class did an experiment. The teacher took a piece of copper sheet and placed it in the flame of a burner. What happened? Would you see a change in the copper? The teacher then held a piece of steel wool in the flame. What happened?

When heated, the steel wool and the copper both changed. They combined with oxygen to form a new substance. The way they changed when they combined with the oxygen in the air is known as a chemical change, or **chemical reaction.** How substances combine for chemical reactions is determined by their chemical properties.

Both the steel wool and the copper combined with oxygen in the air. Many substances combine with oxygen. When paper is heated by the flame from a match, it combines with oxygen and changes to ash. Iron rusts when it combines with oxygen at room temperature. Aluminum hardly changes in the air.

Chemical properties are those that can be described only when a change occurs in a substance. Sodium combines with chlorine to form sodium chloride. Sodium chloride is known as table salt. When sodium and chlorine react chemically with each other, they are both changed. Their chemical properties can be observed when they combine and change. For you to observe and describe a physical property, the substance is not changed into anything else. When sodium chloride is dissolved in water, it is still sodium chloride. It tastes like sodium chloride. And, if the water is boiled away, sodium chloride remains. But sodium chloride has properties that are different from those either sodium or chlorine had before they were combined.

Using What You Have Learned

1. Compare the solubility in water of table salt, barium sulfate, and silver nitrate.

2. Make a saturated solution of hypo at room temperature. Heat the solution and add about ten more teaspoonfuls of hypo. Cover the container. Put it in a refrigerator. What happens when the solution is chilled?

3. Collect small amounts of table salt, granite, quartz, and Epsom salt. Do an experiment to find out which of these substances dissolve readily in water.

4. You have learned that gases as well as solids can dissolve in water. What is the effect of heat on the solubility of air, a gas? Stir water in a jar to dissolve some air in the water. Stirring the water makes air dissolve more quickly than if the water were not stirred. Another way to dissolve air quickly is to pour water in a jar, cover the jar tightly, and then shake it. Use one of these ways to dissolve air in water.

Now find out the effect of heat on the solubility of air in water. Pour some of the water into a heat-resistant glass jar. Such a jar will not break if it is placed over a fire. A pyrex beaker works well. Heat but be careful not to boil the water. What do you see forming in the water as you start to heat it?

5. What can you add to water to keep it from freezing at 32° F.? Experiment by making one mixture of salt and water and another mixture of alcohol and water. Put the salt water and the mixture of alcohol and water into a freezer. Put a freezer thermometer into each container to measure the temperatures. What mixture freezes first? At what temperature does it freeze?

Observing Crystals

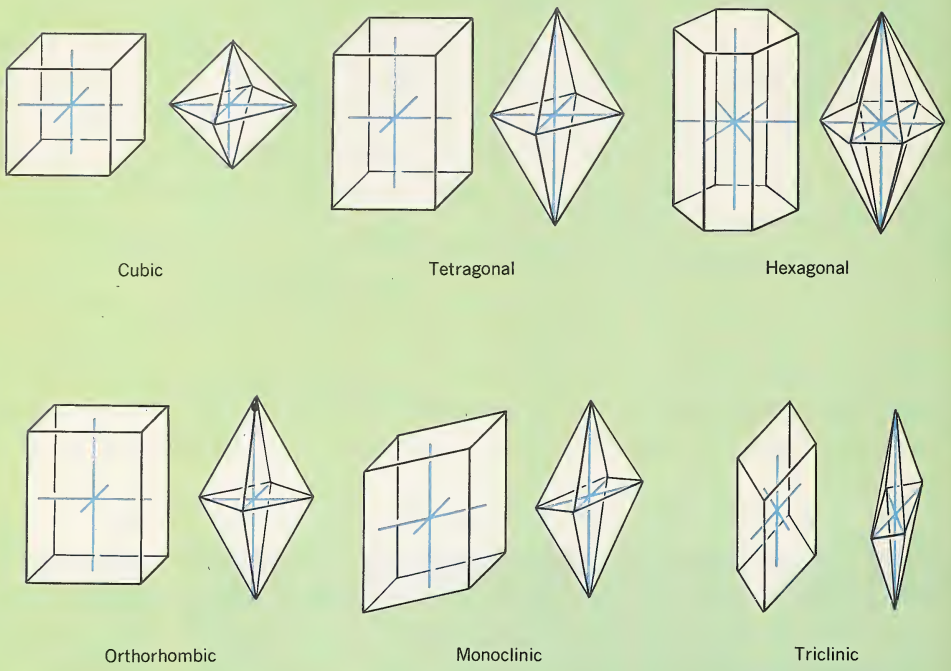
Perhaps you think of crystal as expensive glassware or as the beautiful mineral called quartz. But when the chemist talks about a crystal, he is talking about a solid substance that has a regular fixed shape regardless of its size.

Substances, such as snowflakes, that have a regular fixed shape are known as **crystals.** You have seen many crystals, such as diamonds and table salt.

When large crystals are crushed, the small pieces have the same shape as the larger chunk. When glass is broken, there is no regular pattern to the pieces. However, if a large piece of sodium chloride is crushed, each small piece has the same shape as every other piece. In crystals, because the shape is repeated, small and large particles have the same shape.

Many common substances have a hidden crystalline form. You can find this form in table salt if you examine it with a magnifying glass. Study the shapes of the crystals. Are their shapes different? What are their surfaces like?

Can you tell the names of the crystals below? How are they all similar?



Look at each crystal shape and count the number of sides. What do all the crystal shapes have in common? What differences do you see among the crystals?

Different kinds of crystals have different properties. Some crystals are **cubic,** or six-sided, and others are **octahedral** (ok-tuh-HEE-drul), or eight-sided. Some crystals have a characteristic color.

All crystals have flat faces, sharp edges, and pointed corners. But crystals of different substances may have a different *number* of faces, edges, and corners. Some of the corners may be more pointed than others. And the faces may be different sizes.

Look at the pictures above. These are the six basic crystal shapes. Under each shape you will find the name of this shape.

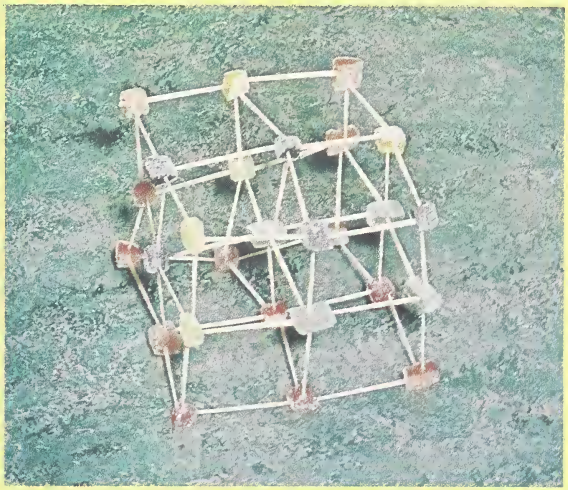
How Can We Understand Crystal Structure?

What You Will Need

a box of toothpicks soft wax or gumdrops

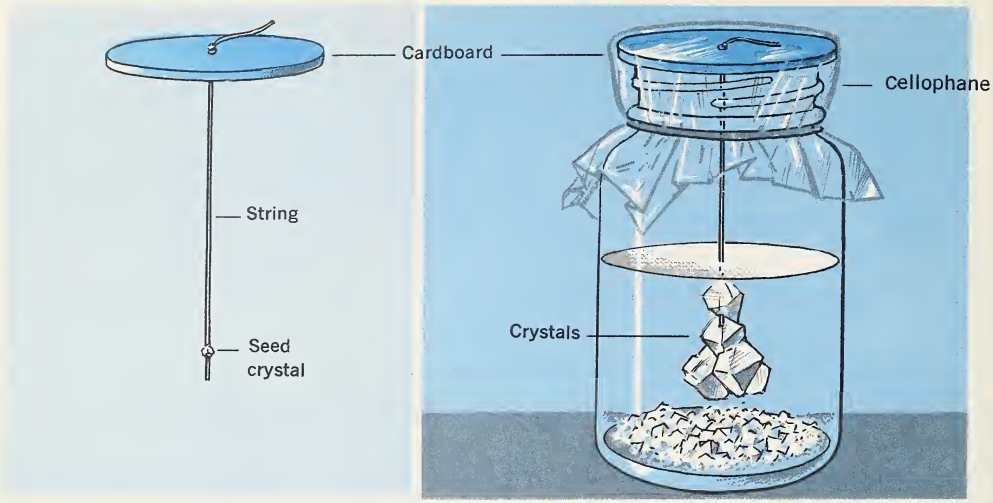
How You Can Find Out

1. Make 27 small (¼-inch) balls of soft wax.
2. Using 12 toothpicks, connect 8 balls of wax to make a cube.
3. Using 42 toothpicks and 19 balls of wax, add to the first cube so that it is 2 toothpicks long, 2 wide, and 2 high.
4. Continue to build the toothpick structure, but add half a toothpick at any point instead of a whole one. (You will, of course, need additional balls of wax.)



Questions to Think About

1. What happens to the shape of the cube as you continue to build with full-sized toothpicks?
2. What happens to the shape when half-sized toothpicks are used? What does this change tell you about crystal structure?



Tie the thread around the seed crystal. Attach the thread to a cardboard cover cut to fit the jar. Place cellophane over the cardboard cover as shown in the picture.

Growing Crystals

To grow salt crystals, you begin with a single salt crystal. This crystal is called the "seed." Can you tell why? Hold the "seed" in some water which has as much of the same kind of salt in it as can be dissolved in the water. As you know, this is called a saturated solution. The "seed" will use the salt from the solution and will become larger.

To make sure that there will be enough salt for the "seed" to grow, use a solution that has been heated. Hot water can dissolve more salt than cold water can. As the solution cools, it becomes **supersaturated.** A supersaturated solution has more salt than is found in a saturated solution. The extra salt dissolved at the higher temperature will come out of the solution as it cools, and will help your "seed" to grow. How does the supersaturated solution help the "seed" to grow?

Any single crystal can be used as a "seed" for growing crystals. It is not hard to grow a crystal for study from salts like chrome alum or potash alum. Either of these chemicals will grow well and will give you beautiful crystals.

Prepare a saturated solution by doing the following: Stir 4 ounces of the alum into 19 ounces of water. Then heat the

mixture in a heat-resistant jar to about 122° F. Can you tell why the mixture should be heated?

You will need only a small part of the solution to obtain a "seed." Pour an ounce of the solution into a saucer, and store the rest in a Mason jar. You will use the stored solution when you are ready for the growing stage.

Let the solution in the saucer stand without moving it. As the solution cools and evaporates, the extra alum, which dissolved at the higher temperature, will come out. Some "seed" crystals will then form on the bottom of the dish. If no "seeds" appear, add an extra pinch of alum to the solution. When "seeds" appear, remove the best one with tweezers and attach it to a piece of thread as shown in the picture.

Now you are ready to grow the "seed." The saturated solution that you have stored in the Mason jar will serve as the growing solution. Add an extra ounce of alum and heat the solution by placing the jar in a pan of boiling water for about ten minutes. Then cover the solution and let it cool.

Prepare a cardboard cover for your jar, and attach the thread with the seed crystal to the cover. Place the cardboard on the jar, and cover the top carefully with cellophane. Put the jar in a cool place where the temperature will not change much. Do not move the jar while the crystal is growing.

Other Ways of Growing Crystals

The chemical phenyl salicylate, often called salol, crystallizes easily. Fill a test tube about half full with salol powder. Heat the test tube until the salol changes to a liquid. Set the test tube aside to cool. Do not move the test tube. Now drop a bit of salol powder in the liquid. Watch what happens. Examine some of the crystals with a magnifying glass. Describe what you see.

You have learned that you can grow a crystal in a supersaturated solution. Allowing a saturated solution to evaporate is another way to grow crystal. Evaporation may take several weeks, but it will give you a better-formed crystal than the sealed-jar method.

Prepare a saturated solution of potassium alum as you did before. Attach the seed to a thread. Tie the thread to the center of a stick so that the seed hangs from the stick. Lay the stick across the top of the jar so that the seed is in the solution. Cover the jar to keep out dust, but do not seal it. Put the jar in a cool place where the temperature will not change much. As the solution evaporates, what changes take place?

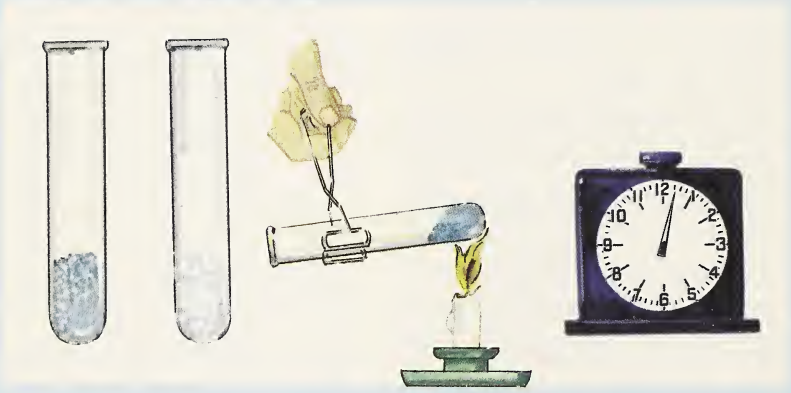
Do All Crystals Contain Water?

What You Will Need

several copper sulfate crystals
several sodium chloride crystals
2 test tubes
source of heat

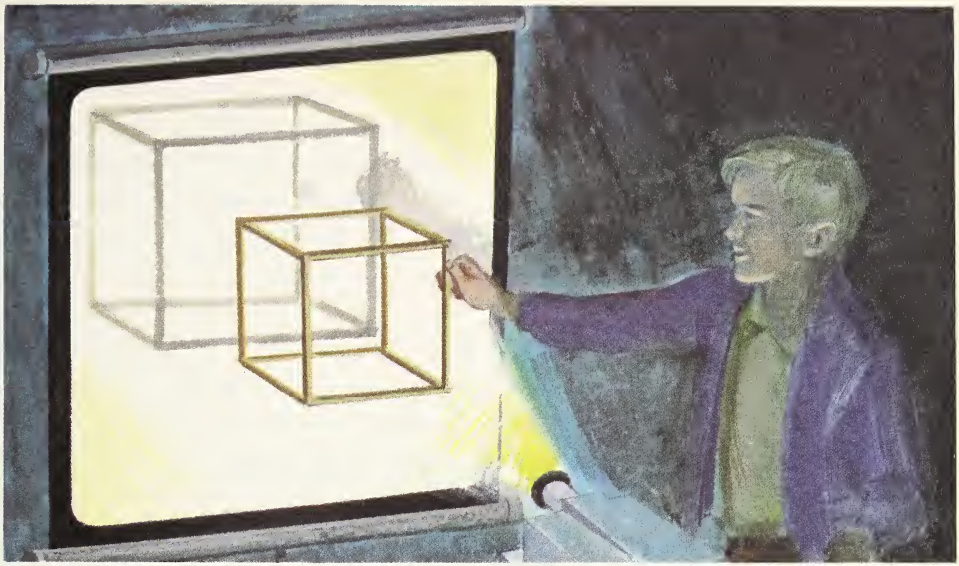
How You Can Find Out

1. Place some copper sulfate crystals in one test tube and some sodium chloride crystals in the other.
2. Heat the test tube containing the copper sulfate crystals for two or three minutes.
3. Write down any changes that you see taking place in this test tube.
4. Heat the test tube containing the sodium chloride crystals for two or three minutes.
5. Write down any changes that you see taking place in this second test tube.



Questions to Think About

1. In which of the two substances was there a change in appearance?
2. How can you explain this change?
3. Is this kind of change found in all crystals?



Crystal Size

The size of a crystal depends partly on the speed with which the crystal is formed. You can do an experiment to see that this is true. Prepare a saturated solution of Epsom salts. Pour the solution into three clean saucers. Put one saucer in a warm place, such as the top of a radiator. Keep another at room temperature. Place the third saucer in a cool spot. Observe the sizes of the crystals that form in the three saucers. In which saucer are the crystals largest? Is it the one from which water evaporated *slowest* or the one from which there was *the most rapid* evaporation?

Finding Out About Crystal Structure

Make a model of a salt crystal like the one you see above. Use balsa sticks. Now hold the model in front of a screen. Darken the room. Shine a light from a slide projector through the model against the screen. Hold the model in different positions and observe the different shadows. You can figure out the shape of an object from the shadows it casts.

In a similar way, scientists learn about the shapes of real crystals. Scientists use X rays. They study the reflections of the X rays, which bounce off the faces and edges of the crystals. They observe

the patterns that the X rays cast on photographic film. The patterns made by different crystals help the scientist to know the shapes of the crystals.

When scientists learn more about how crystals are formed and how they take shape, they will know more about how matter is put together in the universe. Crystal shapes give clues to the structure of matter, because the molecules of matter join together only in certain ways. Now you can understand why the study of crystals is an important part of today's science.

Using What You Have Learned

1. Will a "seed" crystal of one substance grow in a solution that has been made from a different substance? For example, will a potassium alum seed grow in a solution of table salt? Experiment to see if this will happen.

2. Cut out about twenty squares of the same size from construction paper. Put them together on your desk to form a regular fixed shape. Now cut some rectangles, triangles, and other shapes, of various sizes, like those you see in the drawing. Can you fit these new shapes into your earlier fixed pattern? In what way are the paper shapes like the crystal shapes?

3. Get a large piece of rock salt. Break it up with a hammer. Examine the small pieces with a hand lens. How are these small pieces like the bigger piece?

4. The following chemicals can be used for crystal growing: ammonium dichromate, chromium potassium sulfate, cobalt chloride. Try growing crystals of these chemicals using each of the two ways described in this unit.

Elements, Atoms, and Molecules

You have learned that crystals have fixed shapes. Chemists study these fixed shapes very carefully to see how crystals are made. By studying crystals, scientists have learned that all matter is made of some very simple materials.

Elements

For thousands of years, many men believed that all substances are made of a few simple things put together in many different ways. A long time ago, people believed that everything was made of fire, air, earth, and water.

It is now known that everything in the universe is made of one or more of the more than one hundred different substances called **elements** (EL-uh-ments). A substance that cannot be broken down into other substances is an element. All substances we know about are either elements or combinations of elements.

The elements are like the letters of the alphabet. Letters can be put together to make thousands of different words—from *aardvark* to *zymurgy*. The elements can be arranged and rearranged to make the many different materials that we use every day. Everything is made of these elements in various combinations. The paper in the book you are reading, the chair on which you are sitting, and the fabric in the clothes you are wearing are all made of elements. Even *you* are made of many different combinations of elements.

Look at the list of some important elements on page 190. The symbols for the elements and some of the ways in which these elements are found in nature or are used by men are also listed. A chemical symbol usually consists of the first one or two letters of the name of the element. (Some symbols come from the Latin names of elements.) Chemists use these symbols to stand for the various elements. It takes less time and space to write the symbol than to write the full name of the element.

Hydrogen is the lightest element found in nature. Uranium is the heaviest. Several elements heavier than uranium have been made by scientists, but these elements last only for very short periods of time. Berkelium, lawrencium, and californium are examples of man-made heavy elements.

Nature is made up mostly of the light elements. In fact, hydrogen, the lightest element of all, makes up about 76 per cent of the universe. Helium, the next lightest element, and hydrogen

Some Important Elements

Element	Symbol	Found In
ALUMINUM	Al	airplane parts, kitchenware
BROMINE	Br	medicines
CALCIUM	Ca	chalk, bones of the body, teeth
CARBON	C	all living things
CHLORINE	Cl	poisons used to kill germs
CHROMIUM	Cr	plated automobile parts
COPPER	Cu	wire
GOLD	Au	jewelry
HELIUM	He	lighter-than-air craft
HYDROGEN	H	water
IODINE	I	poisons used to kill germs
IRON	Fe	steel
LEAD	Pb	paint, plumbing
MERCURY	Hg	thermometers
NICKEL	Ni	batteries
NITROGEN	N	meat, cheese
OXYGEN	O	all living things
POTASSIUM	K	fertilizers
SILICON	Si	sand, glass
SILVER	Ag	jewelry
SODIUM	Na	table salt
SULFUR	S	insecticide, medicines
URANIUM	U	nuclear-power plants

make up about 99 per cent of the universe. The other hundred or so elements make up only about 1 per cent of all the matter that exists. Most of the matter in the universe is in the stars, and stars are made almost entirely of hydrogen and helium. The elements found most often in the solid parts of the planet earth are silicon and oxygen. After these, the next most plentiful elements are aluminum and iron.

Collect some of the elements in the list on page 190. Bromine, chlorine, calcium, hydrogen, iodine, potassium, and sodium are difficult to get and can be very dangerous. But you should be able to find some of the others, like iron and aluminum. Discover what you can about their properties. Are they solid, liquid, or gas at room temperature? Soft or hard? What colors are they?

Atoms

For hundreds of years, scientists tried to discover the building blocks of the substances in the universe. They tried to find out if all elements are made of the same units. They discovered that, if you took any substance and broke it into tiny pieces, you would finally get a tiny piece that could not be divided. Today, scientists know a great deal about that tiny piece of matter. The smallest piece of any kind of matter is called an **atom.** *Atom,* from ancient Greek, means "not able to be cut."

Atoms are so small that no one can see them. Scientists have only been able to make a *model* of an atom. They use the model to explain how an atom must look for the scientist to be able to predict accurately what the atom will do. Scientists have done experiments to tell whether or not their model is useful. They have changed this model from time to time as new discoveries have been made about the atom. The model you will read about in this unit was developed after years of experimenting.

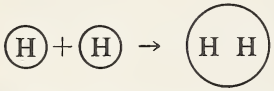
The atoms of each element are different from the atoms of every other element. There are over one hundred elements. Each element has its own kind of atom, but all atoms are made of the same parts—electrons, protons, and neutrons—in various combinations. Atoms are the building blocks of all the matter in the universe.

Molecules

Atoms combine to make up every substance in the universe. When atoms combine, they form a **molecule.**

An atom may combine with another atom of the same type to form a molecule of an element. For example, two

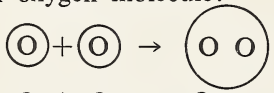
hydrogen atoms form a molecule of hydrogen. Using circles and the symbol for hydrogen, we can easily show the combinations:



Chemists write the combination this way:

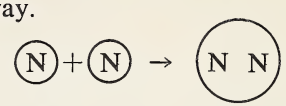
$$H + H \rightarrow H_2$$

Oxygen atoms also combine, and form an oxygen molecule:



$$O + O \rightarrow O_2$$

A nitrogen molecule is formed in the same way.



$$N + N \rightarrow N_2$$

The atoms of hydrogen, oxygen, and nitrogen usually are found in pairs. Each pair is a molecule of that element. A molecule of an element contains only one kind of atom.

Atoms also combine with different kinds of atoms to form molecules. When two or more *different* kinds of atoms combine in a molecule, they form a **compound** (KOM-pownd).

$$Na + Cl \rightarrow NaCl$$

Na = atom of sodium

Cl = atom of chlorine

NaCl = molecule of sodium chloride (table salt)—a compound

$$C + O \rightarrow CO$$

C = atom of carbon

O = atom of oxygen

CO = molecule of carbon monoxide—a compound

What Happens When Elements Combine?

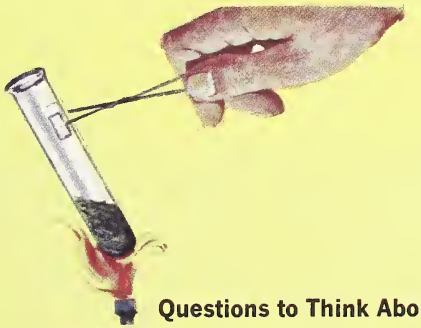
(This should be done only by the teacher.)

What You Will Need

sulfur	magnet	large pyrex
iron filings	source of heat	test tube

How You Can Find Out

1. Use the magnet to test both the iron and the sulfur.
2. Examine both the iron and the sulfur, and write down their properties.
3. Mix the iron and the sulfur together, and test the mixture with the magnet.
4. Fill the test tube one-quarter full with the mixture of iron and sulfur.
5. Heat the test tube for about three minutes in a hot flame. **Do not breathe the vapors! Do not point the test tube at anyone!**
6. Cool the test tube and remove the remaining substance.
7. Test the substance with a magnet, and write down its properties.



Questions to Think About

1. What were the properties of iron and sulfur before heating?
2. Were these properties changed when the iron and sulfur were mixed?
3. What happened when the mixture was heated?
4. What reasons can be given for the change after heating?

Chemical Formulas

Scientists have given every substance a **formula** (FOR-myoo-luh). The formula serves as a sort of recipe, which tells what kinds of atoms the substance is made of and how many atoms there are in a molecule of the substance. A molecule of table salt contains one atom of sodium combined with one atom of chlorine. Its formula is NaCl. A molecule of the oxygen gas you breathe has two atoms of oxygen. The formula for oxygen gas is O_2. A molecule of carbon monoxide has one atom of carbon and one atom of oxygen. The chemist writes the formula for carbon monoxide as CO.

In many compounds, an atom of one element does not combine with only one atom of another element. For example, two atoms of hydrogen will combine with one of oxygen to form a molecule of water. The formula for water is H_2O. Two atoms of oxygen combine with one atom of carbon to form carbon dioxide, CO_2. Three atoms of hydrogen combine with one atom of nitrogen to form a molecule of ammonia gas, NH_3.

Look below at the formulas for common compounds. By referring to the symbols of the elements on page 190, you can tell what elements are in each of the compounds. You also can tell from the formula how many atoms of each element are in a molecule of each compound.

The chemist must know what elements are found in many different compounds. Only then can the chemist know how to use the compounds and predict what will happen when they are mixed with other compounds. For example, baking soda has the formula $NaHCO_3$, and acetic acid, found in vinegar, has the formula $HC_2H_3O_2$.

Formula	Substance
$C_{12}H_{22}O_{11}$	table sugar
H_2O_2	hydrogen peroxide
SiO_2	sand, silicon dioxide
$CaCO_3$	chalk, calcium carbonate
Fe_2O_3	rust, iron oxide
CCl_4	carbon tetrachloride

You can see what happens when these two substances are put together. Put about one-half teaspoonful of baking soda into an empty jar. Add one or two ounces of vinegar. Bubbles form immediately. This means that baking soda and vinegar react to produce a gas. What gas is it? How would you find out?

You can find out what gas it is by observing its properties. This is what the chemist does. Look at the formulas of the substances which you have used. Can the gas contain nitrogen, argon, chlorine, or helium? There is no N or A or Cl or He in either baking soda or acetic acid. But there are some oxygen atoms, O, and some hydrogen atoms, H,

Properties of Common Substances

Substance	Formula	Properties
HYDROGEN	H_2	Gas at room temperature; lighter than air; explosive; odorless; colorless.
OXYGEN	O_2	Gas at room temperature; slightly heavier than air; supports burning; odorless; colorless.
WATER	H_2O	Liquid at room temperature; odorless; colorless.
CARBON DIOXIDE	CO_2	Gas at room temperature; heavier than air; smothers flames; odorless; colorless.
CARBON MONOXIDE	CO	Gas at room temperature; about the same weight as air; burns in air; colorless.

present. The gas could be either a combination of both or a combination of one with some other element. What would you do to find out?

The table on page 195 shows some of these possibilities. Compare the properties of the gas obtained with those of the gases in the table. Which is it?

Note that the properties of compounds are not the same as the properties of the elements of which the compounds are made. The element carbon is usually a black solid that burns readily. Coal is mostly carbon. Oxygen is a colorless gas that enables burning to take place. Yet carbon dioxide is a colorless gas that does not burn. Hydrogen is a highly inflammable gas. Oxygen enables burning to take place. But water, a compound of these two gases, is a liquid used to fight fires.

When two or more elements combine to form a compound, no atoms are lost or added. There are as many atoms in the compound iron oxide as in its elements, iron and oxygen. Scientists can measure the substances to prove this. In a compound the atoms are rearranged, but their number stays the same.

The Structure of Atoms

Have you ever dragged your feet across a thick rug and then touched a metal object? Did you get a shock? This is an example of static electricity.

You can make static electricity in another way. Rub your comb with a piece of wool. Touch the comb to a pile of tiny pieces of paper. What happens? Does the comb attract some papers? Rub a balloon against your sweater. Is the balloon then attracted to the wall or ceiling?

In each of these experiments, you discover something about a property of matter. All substances have *positive* and *negative* charges. Ordinarily, every substance is *neutral.* That is, it has as many positive charges as negative charges. They neutralize each other. Right now, your desk is electrically neutral. The book you are reading, your chair, your pencil, and the flag in your room are also neutral.

Scientists have concluded from static electricity experiments and other experiments that every atom is made up of particles, most of which are charged. Scientists have decided this on the basis of their experiments, though no one has ever seen an atom or its particles.

Look at the model of the hydrogen atom on page 199. It is the simplest of the over one hundred different kinds of atoms. In the center of the atom is a **nucleus.** The nucleus is made up of one

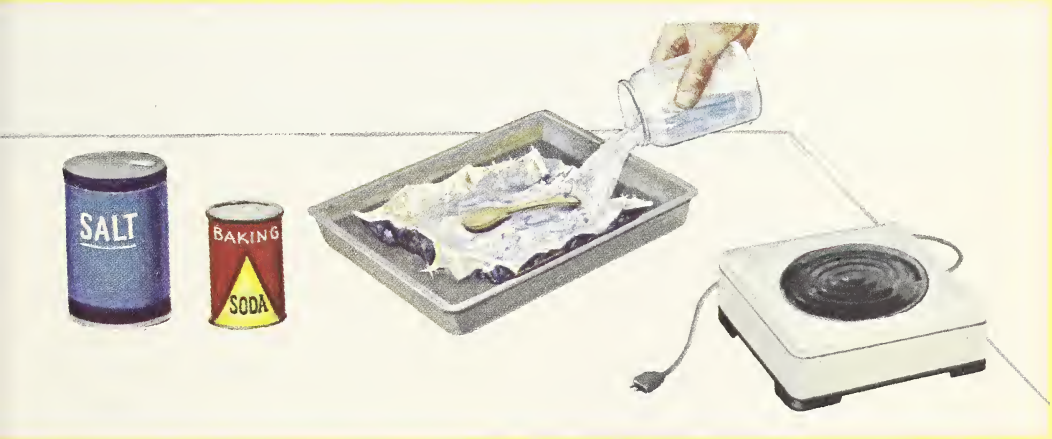
Can Chemical Changes Be Reversed?

What You Will Need

- a piece of aluminum foil
- 1 tarnished silver object
- 1 small pan
- 1 pint of water
- ½ teaspoonful of table salt
- ½ teaspoonful of baking soda
- source of heat

How You Can Find Out

1. Place the tarnished silver object on a piece of aluminum foil in the bottom of the pan.
2. Dissolve ½ teaspoonful of table salt and ½ teaspoonful of baking soda in 1 pint of water.
3. Add the solution to the pan with the silver object.
4. Boil the mixture until you see changes.



Questions to Think About

1. What changes did you see in the materials in the pan?
2. How can you explain these changes?
3. From this experiment can you tell what chemical change takes place on film when you take a photograph?

OBSERVATION

How Can Invisible Objects Be Studied?

What You Will Need

pencil	rubber stopper	small box
partner	cellophane tape	

How You Can Find Out

1. Do not tell your partner what you are putting into the box.
2. Place the stopper or the pencil in the box.
3. Tape the box closed.
4. Give the box to your partner and ask him to tell you what is in the box *without opening it*.
5. Tell your partner that he can shake the box, turn it over, or do whatever he wishes to identify the object inside.

Questions to Think About

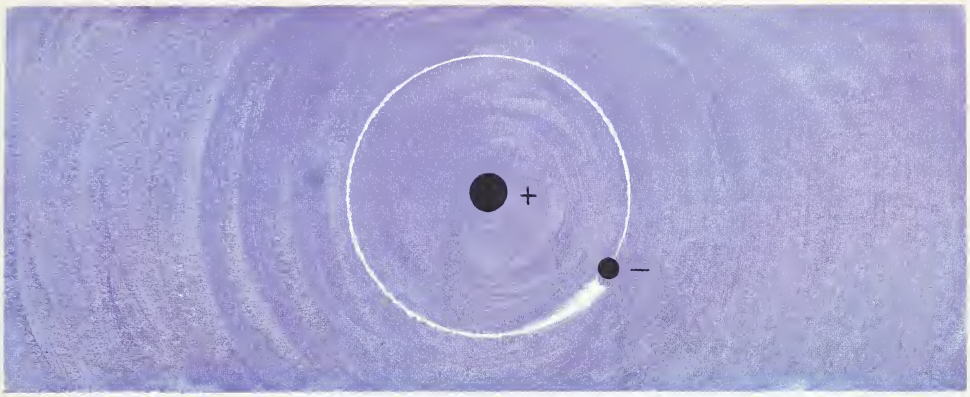
1. How does your partner's work resemble that of scientists?
2. Did your partner identify the object in the box?
3. How did he get his answer?

positively charged particle called a **proton** (PROH-ton). Notice in the diagram that a plus sign (+) is used for a positive charge.

Moving around the nucleus is one negatively charged particle called an **electron** (ih-LEK-tron). In the diagram a minus sign (−) is used for a negative charge. The electron moves in a path, or **orbit** (OR-bit), around the nucleus. The electron moves so rapidly that its position in orbit cannot be spotted exactly.

All other atoms have another kind of particle in the nucleus. This particle is called a **neutron** (NOO-tron). As you might guess from the name, the neutron is neutral. It has no electrical charge.

The hydrogen atom has exactly one positive charge and exactly one negative charge. The hydrogen atom is neutral. Most atoms are neutral. You will find that in most atoms the number of protons (positively charged) is equal to the number of electrons (negatively

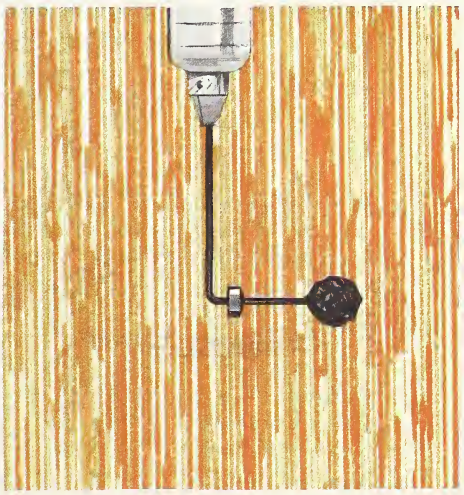


Hydrogen atom

charged). When the number of positive charges is equal to the number of negative charges, the total charge is zero.

This electrical balance can be upset. Some substances are electrically changed when they are rubbed. For example, the charges of a hard rubber comb, hair, many plastics, a balloon, and a wool sweater can all be changed. These substances become charged when they gain or lose electrons. If a substance gains electrons, it become negatively charged. If it loses electrons, it becomes positively charged.

For an idea of how the hydrogen atom might look, insert a long piece of baling wire into the bit socket of a hand drill. Bend the wire into an L-shape, as you see in the drawing. Slip a bolt onto the corner of the L to stand for a proton. Make a small ball from metal foil and stick it on the end of the wire. The foil ball stands for an electron. Spin the "atom." Do you see a blur where the electron is spinning?



In this model of the atom, the electron travels in a path you can see. In a real atom, the place where the electron is located would appear as a blur because the electron travels so fast. The hydrogen electron orbits the nucleus at least 7 million billion times a second!

Orbits of Particles in Atoms

Here are diagrams of helium and lithium atoms. Helium has two protons and two neutrons in the nucleus. It has two electrons in an orbit around the nucleus. Lithium has three protons and four neutrons in the nucleus. Three electrons circle the nucleus.

Notice that one of the lithium electrons has a longer orbit than the other two. Most atoms have several orbits and only a certain number of electrons can fit into any one of them. The orbit nearest the nucleus in any atom holds no more than 2 electrons. The next orbit holds no more than 8. The third orbit holds no more than 18. The fourth orbit holds no more than 32. Usually the inner orbits fill with electrons before the outer orbits.

Oxygen contains 8 protons and 8 neutrons in the nucleus. It has a total of 8 electrons: 2 in the first orbit and 6 in the second.

Atomic Mass

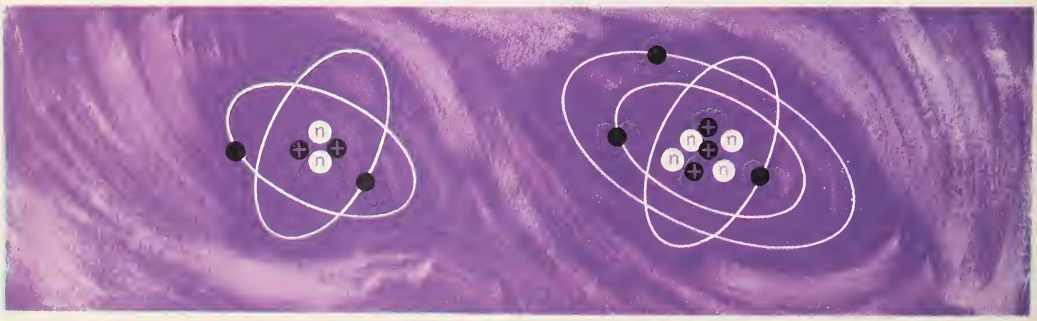
The **atomic mass** is the total number of particles in the *nucleus* of the atom. To find the mass number of an atom, add the number of protons and neutrons.

Thus, hydrogen has a mass number of 1 (1 proton, no neutron); helium has a mass number of 4 (2 protons + 2 neutrons = 4).

The mass number of lithium is 7 (3 protons + 4 neutrons = 7).

Helium atom

Lithium atom



Atomic Mass

Element	Symbol	Protons	Neutrons	Electrons	Mass Number
HYDROGEN	H	1	0	1	1
HELIUM	He	2	2	2	4
LITHIUM	Li	3	4	3	7
BERYLLIUM	Be	4	5	4	9
BORON	B	5	6	5	11
CARBON	C	6	6	6	12
NITROGEN	N	7	7	7	14
OXYGEN	O	8	8	8	16
FLUORINE	F	9	10	9	19
NEON	Ne	10	10	10	20
SODIUM	Na	11	12	11	23
MAGNESIUM	Mg	12	12	12	24
ALUMINUM	Al	13	14	13	27
SILICON	Si	14	14	14	28
PHOSPHORUS	P	15	16	15	31

Since each element has a different number of particles in its atomic nucleus, each element has a *different* mass number.

Above is a list of the first fifteen elements. It shows the number of protons, neutrons, and electrons in each of their atoms. The mass numbers of these elements are also shown.

You know that a proton has a positive charge and an electron has a negative charge. But remember that most atoms are neutral. Helium has 2 protons, and it also has 2 electrons. The atom has no

EXPERIMENT

Do Properties Change When Elements Combine to Form Compounds?

What You Will Need

copper filings
iron filings
copper sulfate solution, $CuSO_4$
copper chloride solution, $CuCl_2$
ferric chloride solution, $FeCl_3$
ferric sulfate solution, $Fe_2(SO_4)_3$

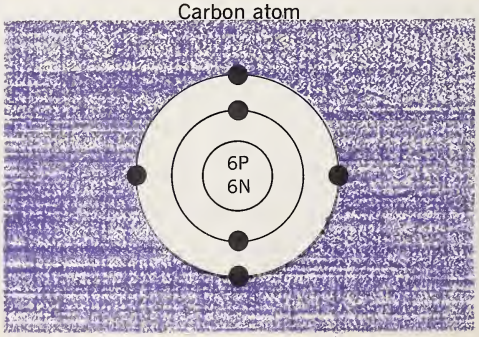
How You Can Find Out

1. Examine the color of each substance.
2. How would these substances be grouped according to their colors?
3. Mix each substance with water.

Questions to Think About

1. What elements are in each of these substances?
2. Which substances dissolve in water?
3. How do the solutions get their colors?
4. Is there a difference in color between copper and its compounds?
5. Is there a difference in color between iron and its compounds?
6. Are there other properties of these elements which changed when they formed these compounds?
7. How can you determine if other elements behave in the same ways?

charge. On this page, you see a carbon atom. It has 6 protons and 6 electrons. The carbon atom is neutral.



Ions

The top diagrams on page 203 show two neutral atoms—one of sodium, the other of chlorine. Notice that sodium has one electron in the outer orbit and

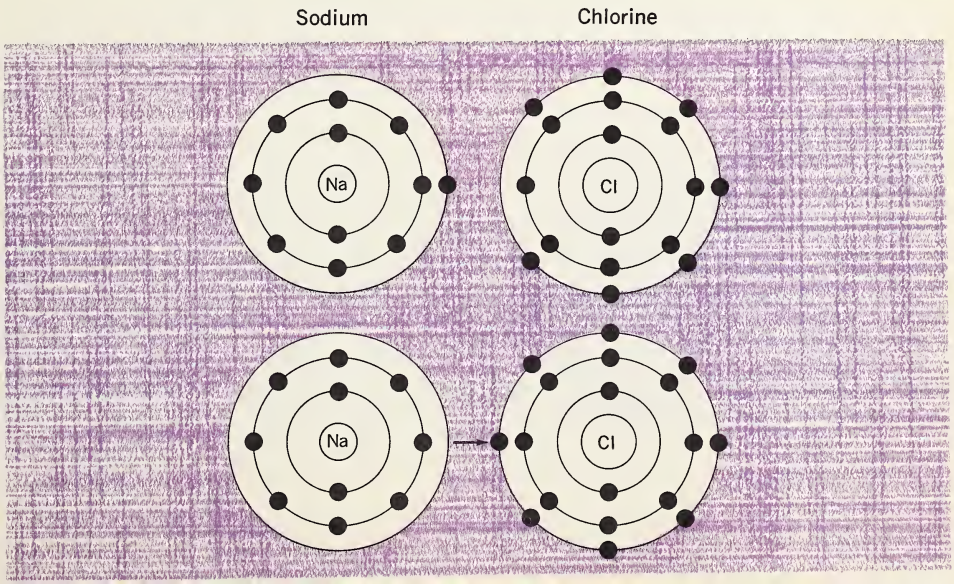
chlorine has seven. When sodium and chlorine atoms come together, the single electron in the outer orbit of the sodium jumps to the outer orbit of the chlorine atom. A chemical reaction produces sodium chloride.

When the single electron jumps from the sodium atom to the chlorine atom, the sodium atom is left with an extra proton. Therefore, the sodium atom now has a positive charge. But the chlorine atom has an extra electron. It now has a negative charge. Since unlike charges attract each other, we can therefore expect that the sodium and chlorine will be attracted to each other.

Atoms that have lost or gained electrons are no longer neutral. Such atoms are called **ions** (EYE-unz). The ions of sodium and chlorine are held together strongly because when they meet they have opposite charges. The atoms become ions.

When elements combine to form compounds, or compounds combine with other compounds, the activity usually takes place among electrons in the outer orbits of the atoms.

When a chemist knows the structure of an atom, particularly the number of electrons in the outer orbit, he can usually tell how the element will combine with other elements. For example, fluorine has seven electrons in the outer orbit. Chlorine also has seven electrons. These elements are not likely to combine with one another. On the other hand, with the same number of electrons in the outer orbit, fluorine and chlorine have similar properties. They



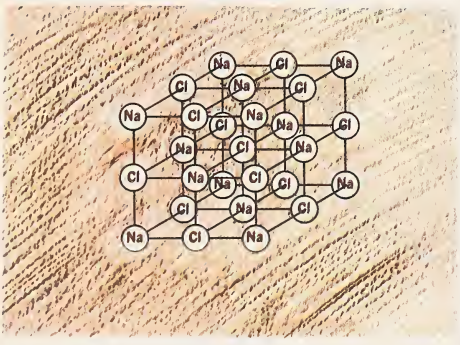
both combine readily with hydrogen and with sodium. Fluorine and chlorine are considered to be in the same family of elements because of their similar properties.

Ions and Crystals

Knowing about ions should help you to understand how crystals grow. You remember that a "seed" crystal was hung in a salt solution. When salts are added to water, a great deal of electrical activity immediately begins. Salt crystals are made up of electrically charged atoms, or ions. The ions are held together by electrical forces. Water weakens these forces and frees the ions. A single ion will gather water molecules around it. The ion is "clothed" in water molecules. When this happens, the salt ion is *dissolved* in water.

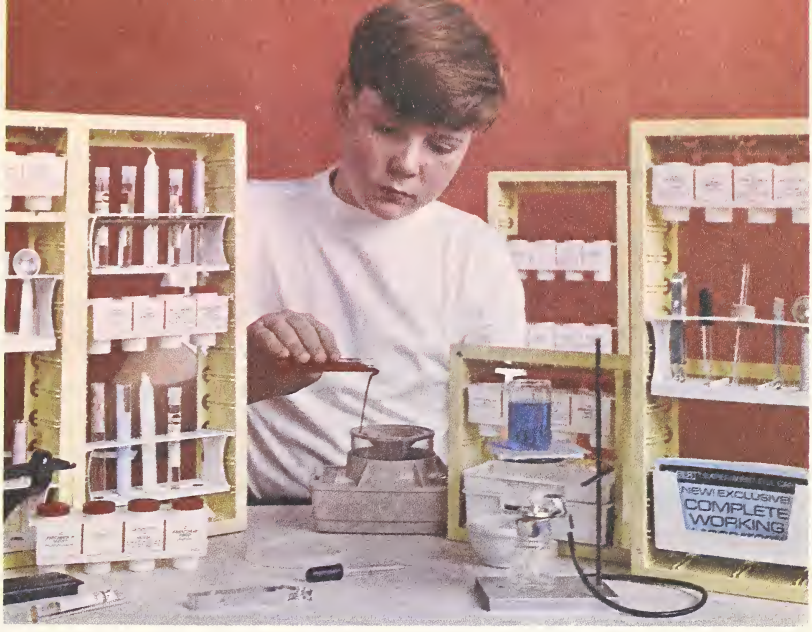
When a seed crystal is placed in a saturated solution, each ion with its surrounding water molecules may be attracted to the surface of the crystal. Where each ion, and its surrounding water molecules, goes depends upon the order of the atoms already present in the seed. Study the model of sodium chloride on the left and note how each ion has found its place in the crystal structure after losing its coat of water molecules. Note the order in the structure of this cubic crystal. Ions will continue to be deposited upon the seed in this orderly fashion until there are no more ions available.

How would you describe this crystal shape? Can you tell the order in the structure of this crystal? You can make a model of the crystal using gumdrops and toothpicks. Why would such a model show you the structure of the crystal better than the drawing does?



Your Use of Chemistry

Perhaps you will make a hobby of the study of chemistry. As you have seen in this unit, there are many experiments you can try. Each one will help you to learn more about the substances that make up all of the things in the universe. When you learn about chemistry, you begin to see an order in the world of materials. Perhaps you will decide to become a chemist and discover more about the materials of which our world is made.



Using What You Have Learned

1. Draw pictures of the following atoms: neon, boron, nitrogen, aluminum, beryllium, fluorine.

2. Helium's outer orbit is "filled." It has two electrons. Do you think it combines readily with other elements? Does this make it useful for certain jobs?

3. What other elements on the list on page 190 have outer orbits which are "filled"?

4. An element has a mass number of 32. It has 16 neutrons. How many protons does it have? What is the element?

5. Read about the discovery of certain elements. Find out what the following scientists contributed to the discovery of elements: Marie Curie, Humphry Davy, Ernest O. Lawrence, Henry Cavendish, Antoine Lavoisier.

WHAT YOU KNOW ABOUT

The World of Chemistry

What You Have Learned

Chemists study the **chemical properties** and the **physical properties** of natural substances and man-made substances. They use **formulas** to tell the kinds and numbers of **atoms** in a substance.

Everything in the universe is made of just over one hundred different substances called **elements.** An element is a substance that cannot be broken down into other substances by ordinary means.

The smallest piece of any element is called an atom. Atoms, either by themselves or combined with one another, make up every substance in the universe. When atoms combine, they form **molecules.** When atoms of more than one kind combine in a molecule, they form a **compound.**

In the center of each atom is a **nucleus.** The nucleus is made up of **protons** and **neutrons.** Moving around the nucleus are negatively charged particles called **electrons.** Atoms that have lost or gained electrons are called **ions.**

The **state of matter** of a substance may be solid, liquid, or gas. A **soluble** substance can dissolve in another substance and make a **solution.**

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

atom	electron	molecule	proton
atomic mass	element	neutron	saturation
crystal	ion	nucleus	solution

Complete the Sentence

Write the numbers 1 to 10 in your notebook. Next to each number, write the word or words that best complete the sentence.

1. A chemist begins a description of a substance by listing its ____?____.
2. The three states of matter are ____?____, ____?____, and ____?____.
3. If a substance dissolves in another substance, it is ____?____.
4. Substances which have a fixed shape are known as ____?____.
5. Everything in the universe is made of just over one hundred different substances called ____?____.
6. The smallest piece of any element is called an ____?____.
7. When atoms combine, they form a ____?____.
8. A kind of recipe that tells what kinds of atoms and how many are in a substance is called a ____?____.
9. A positively charged particle is called a ____?____.
10. Atoms that are no longer neutral because they have gained or lost electrons are called ____?____.

Which Is Which?

Which of the properties listed below are physical properties? Which are chemical properties? List the properties in your notebook and next to each write *physical* or *chemical.*

Ice melts at 32° F.

Salt dissolves in water.

Iron rusts when it combines with oxygen.

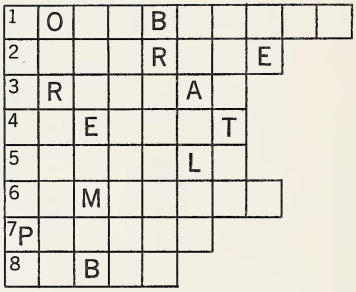
Sodium combines with chlorine to form sodium chloride.

YOU CAN LEARN MORE ABOUT

The World of Chemistry

What's the Word?

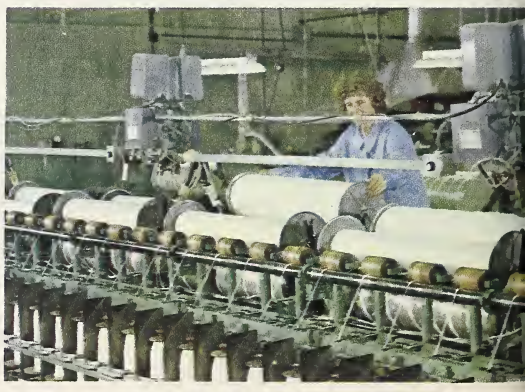
1. An important physical property of any substance.
2. To combine as much of one substance as possible with another substance.
3. A substance with a fixed shape.
4. A substance that cannot be broken down into other substances.
5. A type of recipe used in chemistry.
6. A combination of elements.
7. A positively charged particle.
8. The path of an electron.



You Can Visit

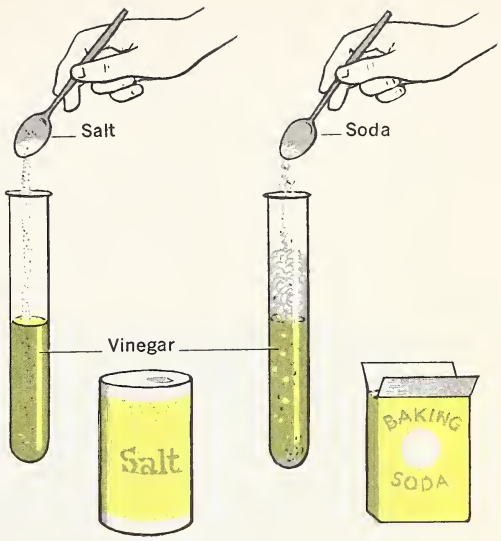
A textile factory is a place where fabrics are made. Perhaps you can arrange to take a guided tour of such a factory.

Try to find out the chemicals that are used for dyes. Ask if there are scientists working for the factory. Find out what they do. Does the factory you visit make materials of dacron, rayon, or nylon? What are the advantages of these materials over wool and cotton?



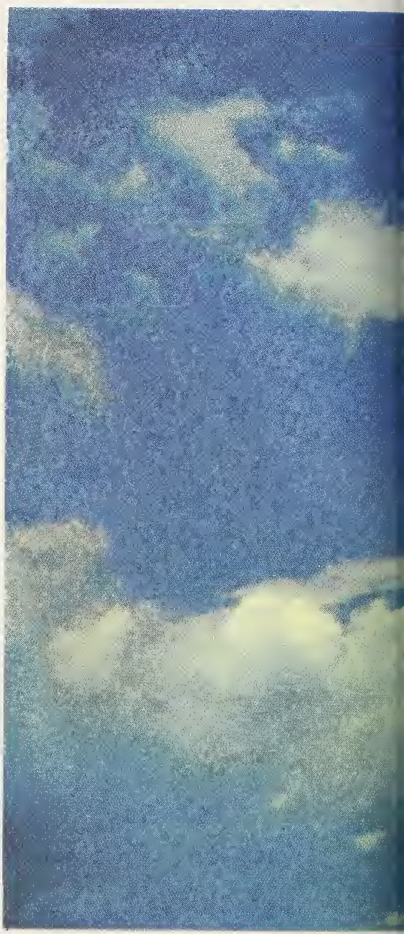
Try This

Here is an experiment to show the difference between a physical and a chemical reaction. Add two teaspoonfuls of salt to a half full test tube of vinegar. What happens? Taste a tiny bit of the solution. How does it taste? Has any chemical reaction taken place? Now fill a test tube half-full of vinegar and this time add two teaspoonfuls of baking soda. What happens? What is forming? Do you see something being changed? Do you see something new being formed? Taste a tiny bit of the liquid in the test tube. Does it taste like vinegar or baking soda? What does the taste tell you? Can you explain what has occurred?



You Can Read

1. *The Story of Chemistry,* by Mae and Ira Freeman. You will read not only about the basic principles of chemistry but also about its applications.
2. *Exploring Chemistry,* by Roy A. Gallant. The history of chemistry from prehistoric times to today's frontiers.
3. *Antoine Lavoisier: Scientist and Citizen,* by Sarah R. Riedman. The life of "the father of modern chemistry."
4. *The Curies and Radium,* by Elizabeth Rubin. The story of this famous team and their work in studying radioactive elements.



7

Probing the Atmosphere

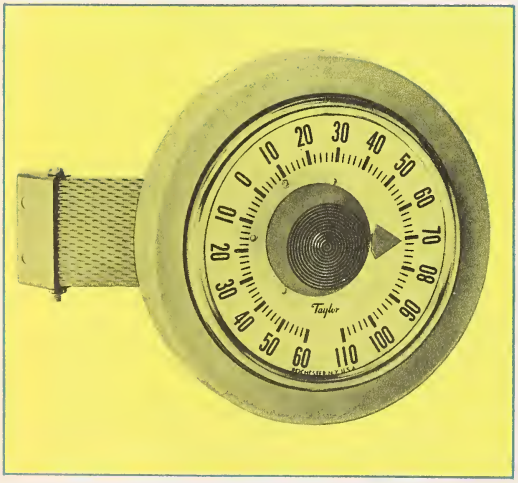
Air and Weather
Keeping Records of the Atmosphere
Weather Maps and Forecasting

The United States Weather Bureau now predicts the weather for thirty days in advance. In the future, it hopes to make three-month predictions. Behind each forecast is a vast amount of research. Space-age instruments are now helping scientists to find out how weather behaves and why it behaves as it does.

Air and Weather

The aims of weather scientists are to make accurate weather forecasts—short-range forecasts and long-range forecasts for a season and possibly for a year. To do this, scientists need a better understanding of what happens in the air.

Below is an outdoor thermometer. How does it differ from an indoor thermometer?



Air Can Be Heated or Cooled

Use an outdoor thermometer to take readings at 9:00 A.M., 1:00 P.M., and 3:00 P.M. Keep the thermometer in the shade. What does the thermometer measure? Are there differences in the readings? Why does the temperature of the air usually change during the day?

If you remember that the temperature of the air changes, then you will understand better how the weather forms.

In the experiment that follows some air in the soccer ball will flow out if you break the seal of the ball by putting a pin into the seal. Then the soccer ball will not weigh as much as it did before. Does the air in the ball have weight? The weight of the pail of sand will not change. The balancing stick will tilt downward toward the heavier object. How will you know that the air that escapes from the ball has weight?

Does Air Have Weight?

What You Will Need

yardstick	inflated soccer ball	pail
sand	pin from soccer ball	chair

How You Can Find Out

1. Suspend the soccer ball and the pail from the yardstick as in the diagram.
2. Keep adding sand to the pail until the soccer ball and the pail balance.

Questions to Think About

1. What can you assume when the soccer ball and the pail balance?
2. Now place the pin in the soccer ball. What happens to some of the air in the ball?
3. What happens to the yardstick? Can you explain why this happens?

Shake the box containing ping-pong balls and golf balls. What do you observe?

The Density of Air Can Change

Take two plastic bags of the same size. Blow them up to the same size and tie each one tightly. Leave one bag in the classroom and put the other one in a freezer. The temperature there should be about 4° F. What happens to each of the bags?

The molecules in the bag with the warmer air move around very rapidly and take up more space. The air molecules in the bag of colder air move around less rapidly; they take up less space.

The activity illustrates a very important fact about weather: *a volume of cold air is denser than the same volume of warm air.* This means that cold-air molecules are closer together and have less space between them than do warm-air molecules.

Cool Air Pushes Warm Air Upward

A model will help you to understand why air rises when it gets warmer and why it falls when it gets cooler. Build a box with clear plastic or heavy celluloid sides. Make it about 1 foot long, 1 foot wide, and 10 inches high. Fill the box with ping-pong balls and golf balls. Marbles may be used if you cannot get golf balls. Shake the box with the ping-pong balls and golf balls roughly. Watch what happens.

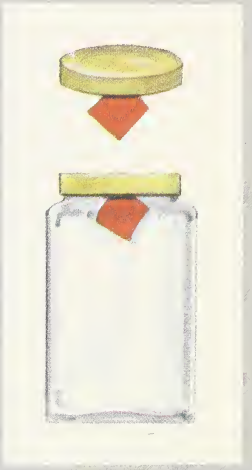
Because the golf balls are heavier, they are pulled more by the earth's gravity. They move downward. The ping-pong balls are pulled less. Also, as they move downward the heavier golf balls force the ping-pong balls upward.

Pretend that each ping-pong ball is a warm-air molecule and that each golf ball is a cold-air molecule. The cold-air

Which Can Hold More Water Vapor, Warm Air or Cold Air?

What You Will Need

2 jars of the same size, with lids
2 pieces of the same cloth, 1 by 2 inches
tape
thermometer



How You Can Find Out

1. Put one jar in the sunlight or on a warm radiator. Leave the other in a freezer. Do not put the lids on either jar.
2. After about half an hour, take the temperature of the air in each jar and record it.
3. Take the two pieces of cloth and wet them. Squeeze out as much water as you can from each. Suspend a piece of cloth from the lid of each jar with tape, as in the picture.
4. Return the cold jar to the freezer. Place the other jar back in the sunlight or on a warm radiator.

Questions to Think About

1. Which cloth dries first?
2. Can you tell why?
3. Which holds more water vapor, warm air or cold air?

molecules are closer together than the molecules of warm air. Cold air is denser than warm air. The cold air is pulled downward more than the warm air. The cold air hits against the warm air. The warmer air is forced upward just as the ping-pong balls were.

You can feel the air push. You can see the air move things. Moving air is called **wind.**

Water Vapor and Air

Water vapor is one of the gases found in air. The amount of water vapor in the air is not always the same.

If the jars in the experiment above are the same size, which jar holds more air? What happened to the water from the wet cloths? The molecules of water left the wet cloths and spread out into the air. We can say this another way.

The water was changed into water vapor. It **evaporated** into the air.

What was the temperature of the cold air? What was the temperature of the warm air? Did the cold or the warm air take up, or evaporate, water more easily? Did the same amount of water vapor get into the air in each jar? Because the molecules of cold air move slowly, more of these molecules fit into a jar. There is more space between the molecules of warmer air in the other jar. The molecules of water vapor fit between the molecules of warm air.

The wet cloth in the jar of warm air dried faster because the water evaporated faster. Water evaporates faster in air that is warm. There is more room between the molecules of warm air. Warm air is less dense than cold air.

Here is a summary of what you have learned about weather and air:

1. Weather takes place in the air.
2. The temperature of the air is always changing.
3. Because the air is made up of molecules, the air has weight.
4. The density of the air changes when the temperature of the air changes.
5. A given volume of cold air is denser than the same volume of warm air.
6. When cold air and warm air are next to one another, the cold air is pulled downward by gravity more than the warm air is. The warm air is forced upward by the cold air.
7. Water vapor is one of the gases in the air. Warm air can hold more water vapor than cold air can.

The Earth's Atmosphere

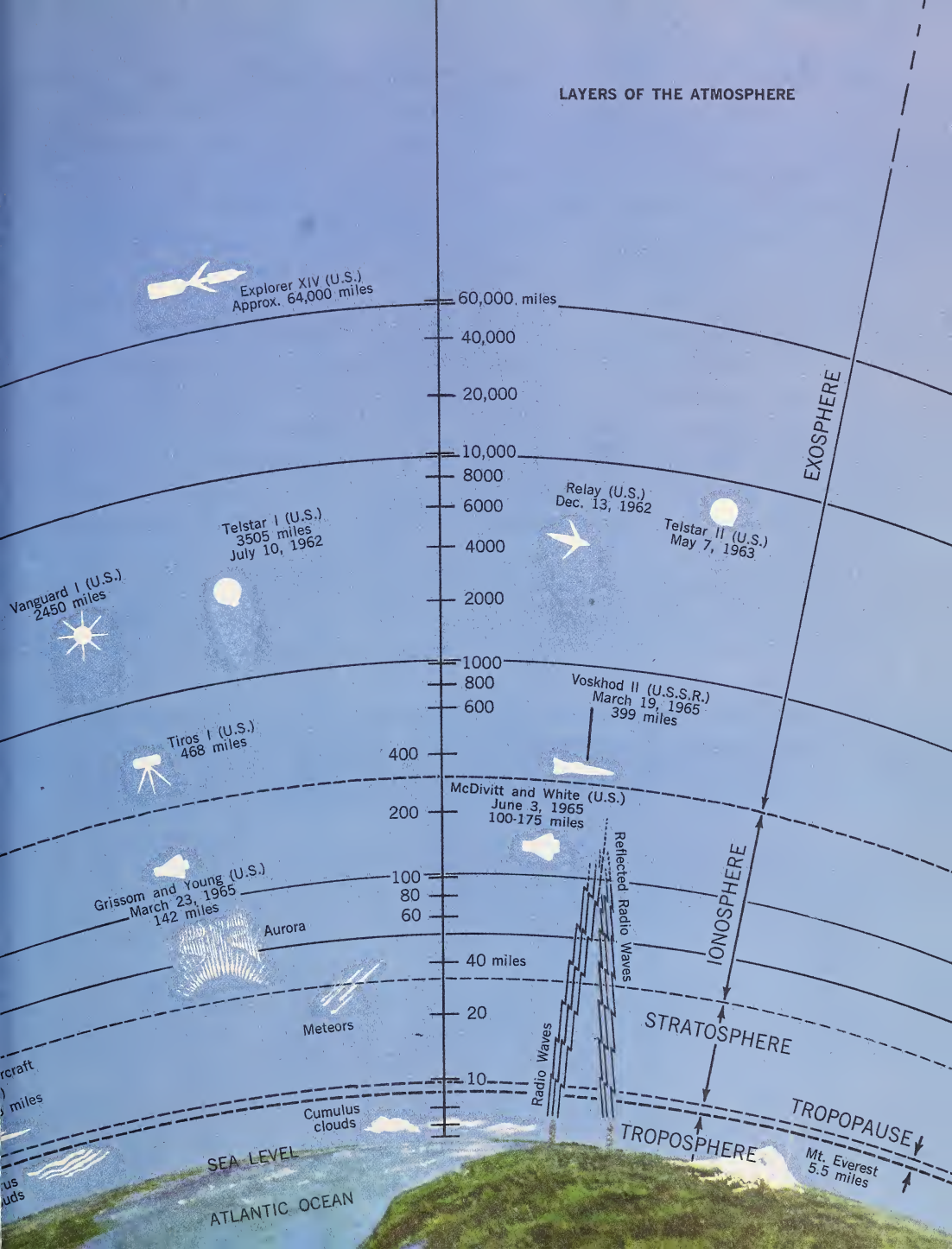
The total amount of air all around the earth is called the **atmosphere** (AT-muss-feer). The atmosphere is like a thick blanket of air around the earth. When you go 100 miles above the earth, there is almost no air.

You live in this blanket of air. The air is a mixture of gases. Most of the earth's air is nitrogen; the rest is oxygen, carbon dioxide, water vapor, and rare gases in small amounts.

The atmosphere is made up of different layers, as shown in the illustration.

Troposphere

The **troposphere** (TROHP-uh-sfeer) is the layer of the atmosphere nearest the earth. It is the part of the atmosphere in which weather takes place. Nearly all the clouds and winds are found in the troposphere. How far out from the earth does the troposphere go? Look at the picture for the answer.


LAYERS OF THE ATMOSPHERE
Explorer XIV (U.S.)
Approx. 64,000 miles
60,000 miles
40,000
20,000
10,000
8000
6000
4000
2000
1000
800
600
400
200
100
80
60
40 miles
20
10
EXOSPHERE
Relay (U.S.)
Dec. 13, 1962
Telstar II (U.S.)
May 7, 1963
Telstar I (U.S.)
3505 miles
July 10, 1962
Vanguard I (U.S.)
2450 miles
Voskhod II (U.S.S.R.)
March 19, 1965
399 miles
Tiros I (U.S.)
468 miles
McDivitt and White (U.S.)
June 3, 1965
100-175 miles
Reflected Radio Waves
IONOSPHERE
Grissom and Young (U.S.)
March 23, 1965
142 miles
Aurora
Meteors
Radio Waves
STRATOSPHERE
TROPOPAUSE
Cumulus clouds
TROPOSPHERE
Mt. Everest
5.5 miles
SEA LEVEL
ATLANTIC OCEAN

Tropopause

Above the troposphere, there is a narrow layer of air called the **tropopause** (TROHP-uh-pawz). The tropopause mixes a little with the layer above it and the layer below it.

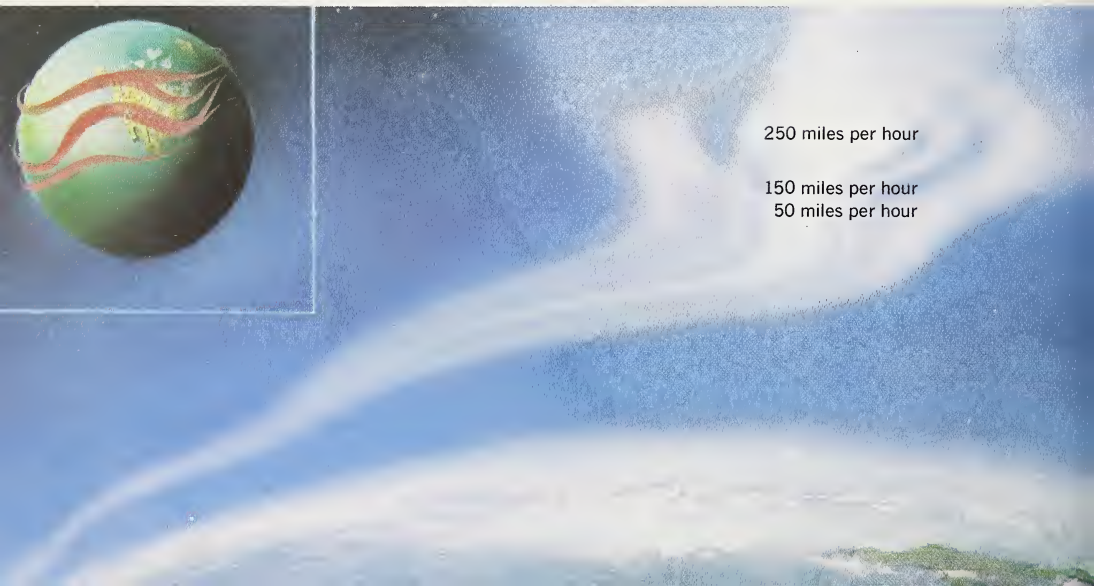
Just below the tropopause in the troposphere are powerful wind currents called **jet streams.** They occur about 20,000 to 35,000 feet above the earth. Jet streams travel eastward and can spread out to about 50 to 300 miles wide. Their average speed is about 150 to 200 miles per hour. These jet streams are strongest at their centers, shift about, and vary in strength. Scientists believe that these winds are caused by differences in the temperatures among layers of the atmosphere.

One jet stream is over the United States. Airplane pilots can sometimes make good use of this jet stream. You already know that the jet streams go from west to east. Is the jet stream more useful when flying from California to New York or the other way?

Stratosphere

The **stratosphere** (STRAT-uh-sfeer) is the layer of atmosphere in which there is almost no weather. There is very little upward air movement. Clouds are seldom found in the stratosphere. Jet pilots like to fly there because it is easy for them to see very far. Also, the lack of air currents makes the airplane ride very smooth. The air is so thin in the stratosphere that there is little friction

Where are the winds strongest in the jet stream? What is the jet stream's direction?



against the plane. Because of this, less fuel is used. Do pilots have to worry about storms in the stratosphere?

Other Layers of the Atmosphere

The **ionosphere** (eye-ON-uh-sfeer) is above the stratosphere. The air in the ionosphere is very thin. The molecules are very far apart. The **exosphere** (EK-suh-sfeer) is the highest layer of the earth's atmosphere. In this layer the air molecules are very far apart.

Why the Earth Stays Warm

The sun gives off rays. Some of these are light rays that make it possible for you to see. Other rays from the sun produce heat when they hit the earth. The heated earth then reflects some of these rays. The reflected rays heat the atmosphere. Do these rays go back out into space? Some do, but most of them are "trapped" by the earth's atmosphere.

You can try this to help you understand the idea. Put your hand against the glass of a sunny window. Then put your hand on the wooden frame of the window. Which feels warmer? When the sun's rays reach the wood, the molecules in the wood become more active. The molecules now have more energy. Heat is produced and goes from the frame to your hand. But the rays can pass through glass. The glass molecules absorb few of the sun's rays. The glass is cool.

Now think of a greenhouse. Flowers can be grown there in the winter. Why is this so? The sun's rays go through the many panes of glass. They hit the soil around the plants. The soil becomes heated and gives off rays of its own. But these rays are different from the sun's rays. These rays *cannot* go back out through the glass. The glass acts like the earth's atmosphere and traps the heat rays. The rays are bounced back down, and the greenhouse is kept warm.

The earth is like a giant greenhouse. The sun's rays pass down through the atmosphere. When they reach the earth, the rays heat the earth. The heated earth then reflects some of the rays. But most of these rays do not pass back up through the atmosphere into space. They are trapped by the atmosphere and reflected back to earth.

The earth's atmosphere controls the amount of heat that the earth gets and loses. During the day the atmosphere screens out dangerous rays from the sun. At night and during the day it acts like a blanket and keeps much of the heat from escaping.

Without the atmosphere the earth would have temperatures similar to those

of the moon. The sun's rays make the temperature on the bright side of the moon about as hot as boiling water. The side away from the sun has a temperature of about —238° F. Why do temperatures on the moon vary so greatly? Can you tell why temperatures on the earth do not vary as much?

Why Are Some Parts of the Earth Warmer Than Others?

You know that the equator has warmer temperatures than the poles. Why are some places on the earth warmer than others? You can find out by doing this activity.

Wet two thermometers. Shine a very bright light on the bulbs of the thermometers. Take readings of each thermometer every 30 seconds. Make a chart of your readings. Your record might look like the one shown at the bottom of this page.

Now put the thermometers in the sun at noontime. Stand one thermometer (B) straight up and lay the other (A) flat. Readings should be taken every 30 seconds. Make a chart of your readings. Your chart might look like the one on the next page.

Which thermometer, A or B, was heated more? Which rays heated the

	Thermometer A	Thermometer B
Reading 1	73°	73°
Reading 2	75°	74°
Reading 3	76°	75°
Reading 4	78°	76°
Reading 5	80°	77°
Reading 6	81°	78°
Reading 7	82°	79°
Reading 8	83°	80°

	Direct Rays (Flat Thermometer, A)	Slanting Rays (Standing Thermometer, B)
Reading 1	77°	76°
Reading 2	80°	78°
Reading 3	81°	79°
Reading 4	83°	80°
Reading 5	82°	78°
Reading 6	82°	78°
Reading 7	83°	79°
Reading 8	84°	80°
Reading 9	84°	80°

thermometers the most? Was it the direct rays or the slanted rays?

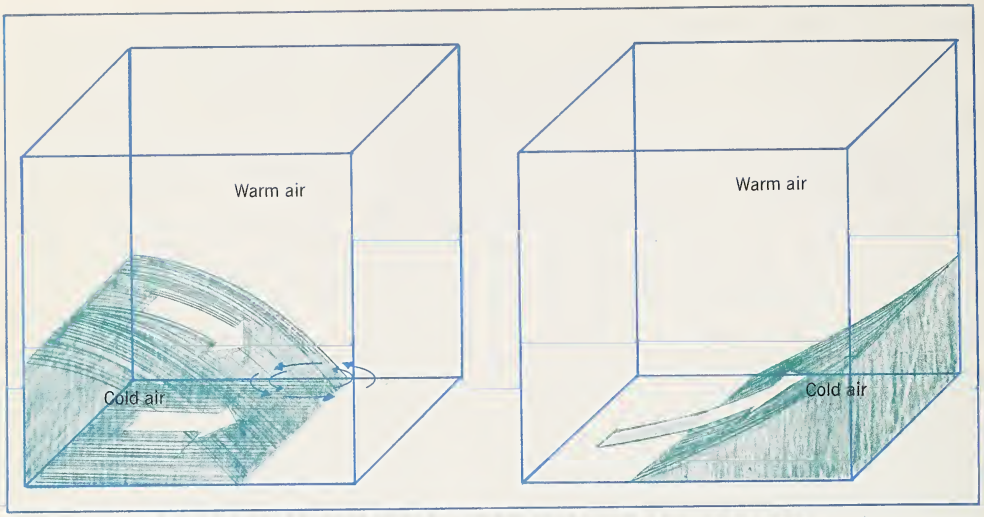
In a similar way, the sun's rays shine more directly on the equator than they do on the parts of the earth that are farther away from the equator. Because the rays are more direct and less slanted at the equator, the rays warm the earth more at the equator.

The air molecules at the equator have more energy. They move faster and take up more room. The air is less dense than the colder air above it. The molecules in the colder air are closer together, and the air is heavier. The force of gravity is greater on the cold air. The cold molecules move downward and force up the warmer air molecules.

The earth is unevenly heated. It also rotates as it revolves around the sun. The uneven heating of air and the rotation of the earth cause the air to move. Such movements of air are called winds.

Air Masses

In an area like the coast around the Gulf of Mexico, the earth becomes very warm. Large amounts of air are warmed by the earth. These large amounts of air are called **masses.** Colder air then



Explain what happens when a cold air mass meets a warm air mass.

moves in and pushes downward. The warmer air is forced upward. As the earth turns, this air goes to the southern United States and toward the east. This moving air, or wind, changes the weather in the places to which it moves.

In parts of Canada, the earth becomes very cold. The great masses of air become very cold and begin to move downward. Because of the turning of the earth, the cold air masses then move south and east. Such masses of moving air change the weather as they move.

When a warm air mass is above an area, the air there is mostly warm and moist. When a cold air mass is over a section of the country, the air there is mostly cool and dry. The weather changes when a warm mass of air meets a cold mass of air.

Sometimes when air masses meet, the cold air mass will push back the warm air mass. Sometimes the warm air mass pushes back the cold air mass. The first picture shows what happens when a cold air mass meets and pushes back a warm air mass. The other picture shows what happens when a warm air mass pushes back a cold air mass.

Highs and Lows

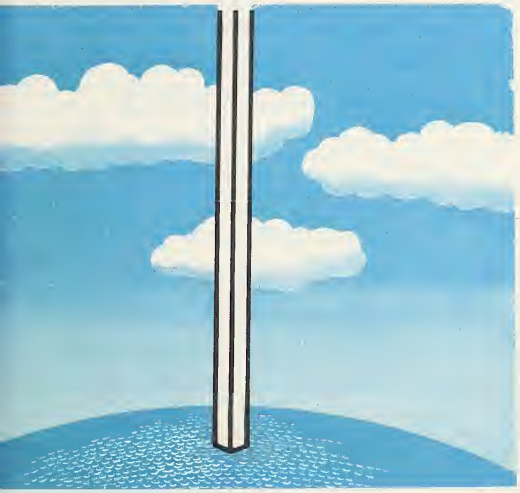
The air is made up of molecules of different kinds of gases. There are millions and millions of molecules in a

thimbleful of air. You cannot see a molecule even when you look through the strongest microscope. One molecule weighs almost nothing. But the billions and billions and billions of molecules piled up for hundreds of miles above the earth weigh a great deal.

A column of air molecules with a base that is 1 inch square, reaching from the ocean to the top of the atmosphere, weighs almost 15 pounds. Because of the weight of these molecules, the atmosphere pushes down on every square inch of the earth with a pressure of almost 15 pounds.

Think of many pillows, each of the same size and the same material.

A column of air 1 inch square at sea level will weigh almost 15 pounds. Will the air be more or less dense below sea level?



Imagine them piled on top of one another. What would happen to the bottom pillow? It has the same amount of stuffing in it as the others, but the weight of the pillows above it pushes the stuffing closer together. What would the middle pillow look like? What would the top pillow look like? Why?

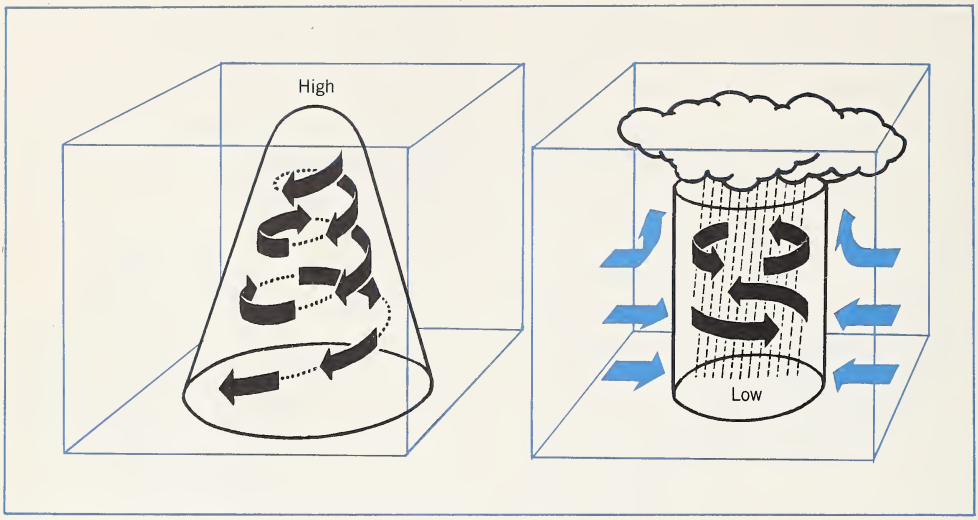
Now think of the air near the earth. The pressure of the air is greatest near the earth. The molecules in the air are pushed closer together. The molecules are closer there because the pressure is greater. The air is dense near the earth. Compare the air at the top of a high mountain with the air at sea level. Where would the molecules be denser? Why?

The pressure of the air on the earth is called **atmospheric pressure.** It is 14.7 pounds per square inch at sea level.

But even in the same place, the atmospheric pressure does not always stay exactly the same. Sometimes it is higher, and sometimes it is lower.

When air pressure is higher in one place than in the others around it, weather scientists say that there is a "high" in that place. When air pressure is lower in one place than in the others around it, they say that there is a "low."

A high-pressure area, or high, starts where the air is cooled. The cooler,



Use the two diagrams to explain how the air moves in a high and in a low.

heavier air starts to drop down, as shown in the diagram. It moves out from the center and forms a whirling wind. The wind whirls in the direction shown by the arrows.

A low-pressure area, or low, forms between highs. The center of the low is the place at which the atmospheric pressure is the lowest. Because the atmosphere around the low is denser, the air begins to form winds that move toward the center of the low. The diagram above shows how air moves in a low.

Highs generally bring fair weather and clear skies. Lows generally bring cloudy weather with rain or snow.

Using What You Have Learned

1. The sun's rays will not go through a mirror. They will not go through a piece of black paper either. Put a mirror and a piece of black paper in the sunlight. After they have been in the sunlight for about 15 minutes, feel them to see which is warmer. Why does one get warmer than the other?

2. Use dots to represent air molecules. Draw a diagram to show why a quart of warm air will not weigh as much as a quart of cold air. In which quart would there be more dots? In which quart would the dots be closer together?

3. Plan some experiments to test the following hypotheses:

a. Water evaporates faster in a strong wind than when there is no wind.

b. When water evaporates from an object, the object cools.

c. Warm water evaporates faster than cold water.

Keeping Records of the Atmosphere

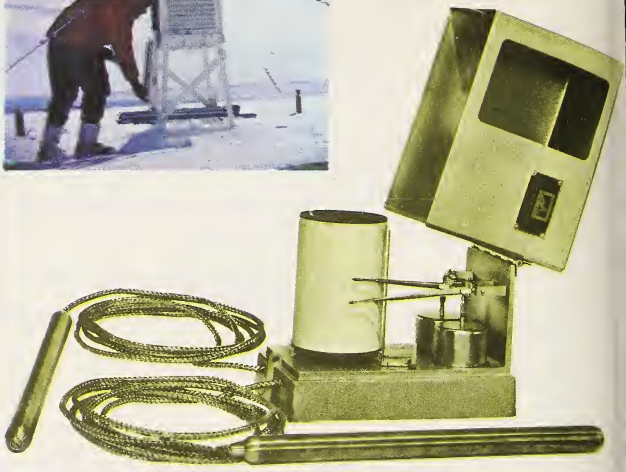
A scientist who studies the weather is called a **meteorologist** (mee-tee-uh-ROL-uh-jist). Meteorologists try to get as much information about the atmosphere as they can to help them forecast the weather.

Forecasting tomorrow's weather starts with finding out what is happening in the atmosphere today. Records of the weather are kept in many different places by many people. In the United States, there are about four hundred weather stations where trained observers keep records of the atmosphere. Some stations are at the tops of high city buildings. Some are on mountaintops. Others are on the plains. There are also weather-observation ships on the ocean. Find out if you have a weather-observation station near you.

The meteorologists use instruments to get information about the atmosphere. You know about some of the instruments. What kind of information does the meteorologist get from each instrument?

Measuring and Recording Air Temperature

Meteorologists use thermometers that are somewhat like the one you have in your classroom. To measure the temperature of the air outdoors, they place their thermometers outside in places where the air moves freely. The thermometers are put in shaded places rather than in the sun. Can you tell why?



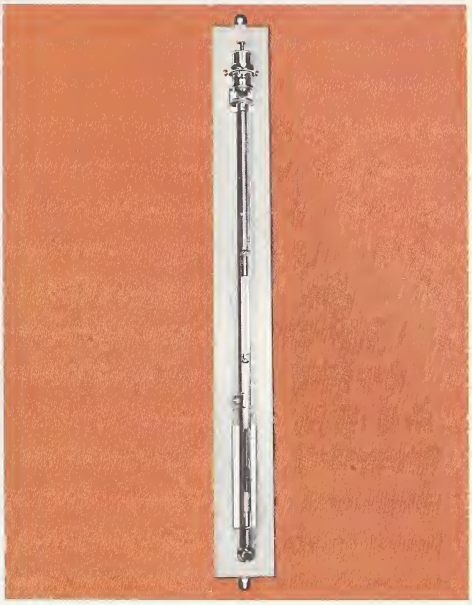
In shelters like the one in the picture above, there are several instruments. There is generally a thermometer. There is also another instrument that measures heat, called a **thermograph** (THER-muh-graf). *Thermo* means "heat," and *graph* means "writing."

One part of a thermograph is a metal tube that contains a liquid. As the temperature of the air changes, the curve of the tube changes. Can you tell why this happens? Another part of the thermograph is a pen that is fastened to one end of a metal arm. The other end of the arm is attached to the metal tube. Look at the picture. As the curve of the tube changes, the pen moves up or down on a sheet of paper that is wrapped around a drum. This drum makes one complete turn in a week. The paper is marked off into days and hours. A new sheet of paper is put on the drum every week. From the thermograph sheets, a meteorologist can tell what the temperatures were all throughout the week.

There are two other kinds of thermometers in the shelter. One is a **maximum thermometer.** This shows the highest temperature for each day. The other thermometer in the shelter is the **minimum thermometer.** This tells the lowest temperature for the day. Ordinary thermometers only tell you what the air temperature is when you look at them.

You can keep a good record of air temperature with your thermometer. The thermometer should be protected from the sun and kept off the ground. Can you tell why? Should it be hung on the north or south side of a building? Six feet from the ground is the best height. It is better to put the thermometer over a grassy place than over a stony place. Why do you think this is so? Take thermometer readings at the same times each day. Why is this important?

Knowing the air temperatures in different places and how the temperatures change helps a meteorologist keep a good record of the weather.



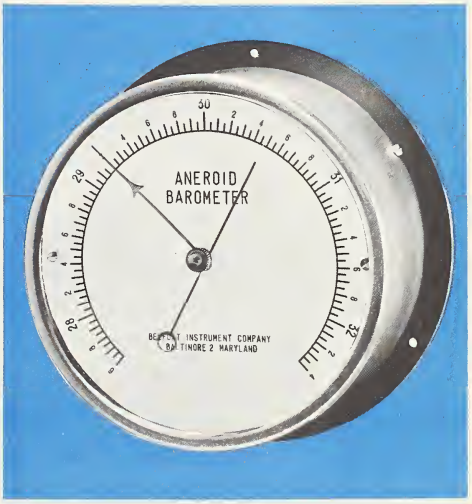
Above you see a mercury barometer; below is an aneroid barometer. Find out how each works.

Measuring and Recording Atmospheric Pressure

Knowing the atmospheric pressure at different places aids the meteorologist in finding the highs and lows. **Barometers** (buh-ROM-uh-terz) measure the atmospheric pressure. The word *barometer* means "weight measure." Mercury barometers are the most exact kinds of barometers.

Listen to a weather report given on the radio or television. What is the barometric pressure?

Another kind of barometer is the **aneroid barometer** (AN-er-oyd). The important part of this instrument is a



DEMONSTRATION

How Does a Mercury Barometer Work?

What You Will Need

glass tube 36 inches long, closed at one end

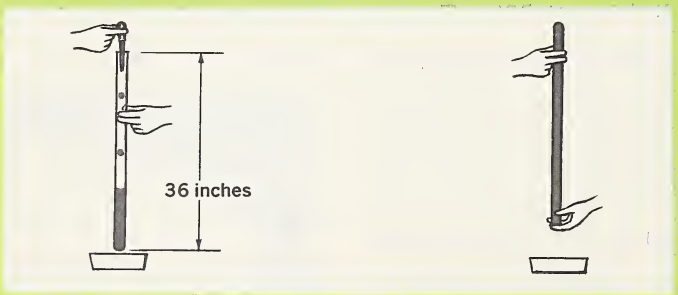
yardstick

mercury in small pan or dish

medicine dropper

How You Can Find Out

1. With the medicine dropper fill the tube with mercury. Hold the tube over the pan or dish of mercury in case some should spill. From time to time, shake the tube up and down to get the mercury past any air pockets. Fill the tube completely.
2. After the tube is filled, hold one finger over the open end and carefully turn the tube upside down in the pan of mercury. Keep your finger on the end until the end of the tube is under the mercury.
3. Remove your finger. Some mercury will run out of the tube.



Questions to Think About

1. Why does some of the mercury run out of the tube?
2. Use the yardstick to measure the vertical distance from the top of the mercury in the pan to the top of the mercury in the tube. Why is atmospheric pressure measured in inches of mercury?
3. As the atmospheric pressure increases, what will happen to the column of mercury in the tube?
4. As the atmospheric pressure decreases, what will happen?

round metal box. Most of the air has been removed from the box. The box is easily pushed in or out. A spring inside the box keeps the sides from caving in. As outside air pressure increases or decreases, the sides bend in or out. As the sides move in and out, they move a needle back and forth. The needle points to numbers on a paper. These numbers tell the atmospheric pressure.

Do you see how an aneroid barometer could be used to obtain a weekly record of atmospheric pressure?

Information from Clouds

Clouds provide much information about weather changes. Do you know how a cloud forms? Water evaporates into the atmosphere and becomes the gas called water vapor. Air is constantly moving, and some of that movement is upward. As the air moves up away from the earth it becomes cooler. Some of the water vapor in the air changes back into a liquid. It is then called a cloud.

Sometimes clouds look very thin. At other times they appear large and puffy. Sometimes the clouds look white. Sometimes they look gray or black. Meteorologists observe the clouds to obtain weather information.

Meteorologists have a system of classification for clouds. They have sorted them into ten main groups. You can learn to know the three groups that are seen most often. You can learn to know what these clouds mean.

The light, puffy clouds that you often see in the sky are called **cumulus clouds** (KYOOM-yuh-luss). *Cumulus* means "pile" or "heap." You often see such clouds in the summer sky.

Cumulus clouds form when warm air containing water vapor rises into the sky. At the place where the water vapor begins to condense, the bottom of a cumulus cloud begins to form. You might think of each puffy cloud as something that is sitting on top of a rising column of warm air. The bottoms of these clouds are usually not more than a mile above the ground. Some cumulus clouds are not very thick, but others may be six or seven miles thick.

Sometimes on a summer day there will be no clouds in the sky in the early morning. But then the sun starts to heat the earth. Later little puffs of cumulus clouds appear. Why?

In the afternoon, as more and more warm air rises, the cumulus clouds get larger and larger. But what starts to happen at sunset? Does as much warm air keep rising? Does as much water evaporate? Do the clouds get larger or smaller?

Cumulus clouds are light and puffy.

CLOUD TYPES

Keep a record for two or three weeks of the kinds of clouds you see each day and the weather for that day. Does knowing what kinds of clouds you are seeing help you to predict the weather?

Cirrus clouds are thin and curly.

Stratus clouds look like gray sheets.

Sometimes the air rises very quickly on a summer day. The tops of the cumulus clouds reach higher and higher. The tops of the clouds may be in very cold air. The air whirls fast that high—sometimes as fast as 100 miles an hour. In other parts of the clouds, cold air is rushing down. Thunderclouds form. Wind, driving rain, and hail can come from these clouds. Sometimes they produce **tornadoes.**

Cirrus clouds (SIR-uss) are high in the sky. Their bottoms are sometimes ten miles from the ground. They are up where winds are blowing fast. Cirrus clouds may move as fast as 120 to 200 miles an hour. They are very thin, curly clouds, made of bits of ice.

Sometimes cirrus clouds appear after several fair days. Quite often they are formed ahead of either a cold or a warm air mass. They are a sign that bad weather is coming in a day or two.

When you see a gray sheet of clouds covering the sky, you are seeing **stratus clouds** (STRAY-tuss). *Stratus* means "layer." Usually, stratus clouds mean that it will soon rain. The rain which comes from such clouds is usually steady.

Measuring Wind Speed and Direction

People often want to know the speed and direction of the wind. Can you see why an airplane pilot would want this information? Would such information be helpful to a man working on a high building or going out in a sailboat?

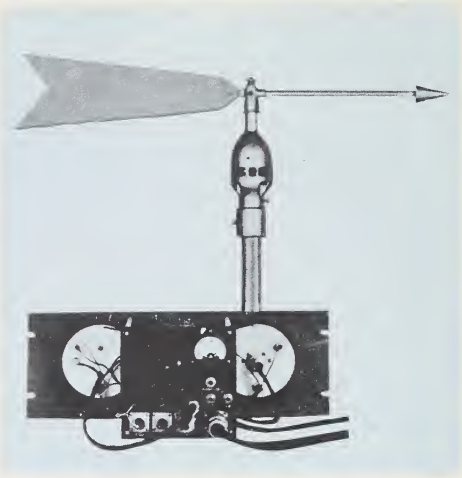
The speed and direction of the wind are important to meteorologists, too. Meteorologists can tell much about the coming weather by studying the wind.

Winds are named for the direction from which they come. What would a wind coming from the southwest be called? What would a wind blowing from the east be called?

A **wind vane** can be used to find wind direction. A wind vane should be kept away from any buildings and trees. Why do you think this should be done?

One type of wind vane is attached to a pen. The direction of the wind is recorded every minute. The pen makes dots on a piece of paper that is attached to a revolving drum. By looking at these dots, the meteorologist can tell when the wind direction changes.

An **anemometer** (an-uh-MOM-uh-ter) is used to find out how fast the wind is moving. There are various types of anemometers. One kind has cups at the ends of arms. When the wind hits these cups, the cups cause the arms to whirl around and around. The stronger the wind, the faster they move. The speed at which they whirl is shown on a dial.



A weatherman reads the wind speed from an anemometer. Can you tell how the anemometer works? How does the wind vane on the right work?

The dial shows the speed in miles per hour. The anemometer, like a wind vane, is usually connected to a recording drum so that the wind speed can be read inside the weather station.

Measuring Relative Humidity

On some days you feel very comfortable. On other days you feel hot and sticky. How you feel depends partly on the amount of water vapor that is in the air.

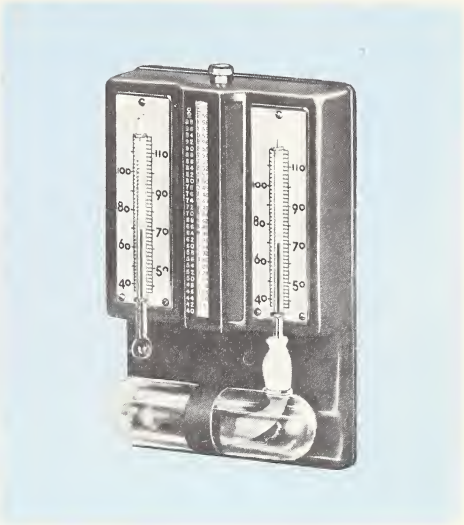
Relative humidity (yoo-MID-uh-tee) is the amount of water vapor in the air compared with the greatest amount that *could* be in the air at a specific temperature. When the air is holding all the water vapor it can, we say the relative humidity is 100 per cent.

The humidity has a great deal to do with your comfort. It is also important in many other ways. For example, if you were planning to hang out laundry, would you want the humidity to be high or low? Or if you were a fire ranger, would you be very concerned about humidity? Fires can start easily on hot days when there is little water vapor in the air. Dead leaves and plants are drier on such days and catch fire more easily.

Warm air can hold more water vapor than cool air. What happens when warm air containing much water vapor becomes cooler?

The instruments used by meteorologists to measure relative humidity are **hygrometers** (hy-GROM-uh-terz). The type of hygrometer most commonly used has two thermometers, one with a wet bulb and the other with a dry bulb.

Here is an example of how the hygrometer works. Suppose the dry-bulb reading was 70° F. and the wet-bulb reading was 65° F. The difference is 5° F. If you move down the 70°-74° column to the 5° line, you come to 78. The relative humidity is about 78 per cent. This means that the air is holding about 78 per cent of the water vapor it could hold at that temperature.



A hygrometer measures relative humidity. Notice that there are two thermometers—one wet-bulb and one dry-bulb thermometer.

Measuring Precipitation

The falling of rain or snow is called **precipitation** (prih-sip-uh-TAY-shun). Meteorologists keep track of how much rain or snow falls every day.

The farmer needs to know about rainfall, especially if he irrigates his crops. He needs to know how much water there will be.

In areas such as the Mississippi Valley, precipitation records are watched very carefully. Heavy snowfalls during the winter may mean floods during the spring. Cities and towns in many other places also keep precipitation records. The water supplies of these cities and

RELATIVE HUMIDITY CHART

Difference between temperatures of dry-bulb and wet-bulb thermometers	Temperature of dry-bulb thermometer		
	65°-69°	70°-74°	75°-79°
2°	90	91	91
3°	85	86	87
4°	80	82	83
5°	76	78	79
6°	71	73	75
7°	67	69	71
8°	62	65	67
9°	58	61	63

Where do you see a funnel on this rain gauge? If 25 inches of water collect in the narrow measuring tube, how many inches of rain fell?

towns may depend on how much rain and snow falls.

The instrument for measuring rain and snow is probably the oldest weather instrument in the world. It is called a **rain gauge** (gayj). As early as 1442, the Korean people used a simple kind of rain gauge to measure precipitation. This simple rain gauge is placed away from buildings and trees. Can you tell why? The rain gauge can measure up to an inch of rainfall.

It is important to measure precipitation to the nearest one hundredth of an inch. An extra one hundredth of an inch of precipitation could mean, for example, that the seeds a farmer has planted will grow. But how do meteorologists measure such a small amount of precipitation?

Meteorologists catch the rain in a large funnel. The water passes through the bottom of the funnel into a narrow measuring tube. The width of this tube is one tenth of the width of the top of the funnel.

The tube is constructed so that if 10 inches collect in the narrow tube, it means that there has been 1 inch of actual rainfall. Why is this helpful in measuring a light rainfall?

Snow is harder to measure than rain. Wind piles it up in drifts. This causes snow to differ in depth from one place to

another. Sometimes snow is gathered in a rain gauge and then melted. Then it is measured. About 10 inches of snow equals the water in 1 inch of rain.

Usually the depth of snow on a flat surface, such as a roof, is measured with a ruler or yardstick. Readings are taken in three places where the snow has not drifted. Then these figures are averaged. This average figure is considered the amount of snowfall. Let us say the readings are 3½, 3¼, and 3¼ inches. To find the average you add all three readings and divide by 3. What is your answer? Do you get 3⅓ inches as the amount of snowfall?

Make a rain gauge. Use a jar with straight sides and a flat bottom. Why should you use such a jar? Where should you place this jar? How can you measure the rainfall?

This gauge will give you accurate precipitation readings only when there is a heavy rainfall. You can build a more useful gauge by copying the weather bureau's gauge.

Pour 1 inch of water into a wide jar. Now pour this water into a narrow jar. This was 1 inch of water in the wider jar, but now, in a longer, narrower jar, it is more than 1 inch. Mark the jar at the exact top of the water in the jar. Now divide the space between the bottom of the jar and your mark into ten equal parts. After you do that, mark off the spaces. What does each mark measure?

By leaving the larger jar outside during rain, you can tell the amount of rainfall. How are you able to do this?

The next time it rains, leave the large jar outside. Then pour all the rain from this jar into your rain gauge. If the water reaches the halfway mark on your scale, there has been one-half inch of precipitation.

Must you always use the same large jar that you used to make your gauge? Why?

Measuring Visibility

How far can you see on a clear day? How far can you see on a cloudy day?

Visibility (viz-uh-BIL-uh-tee) is the distance that you can see along the surface of the ground. Visibility is not always measured with an instrument. The meteorologist at a weather station knows the exact distance to certain objects outside. A tall tree may be one-half mile away. A tall building may be three fourths of a mile away. If the meteorologist can see as far as the tree but no farther, he says the visibility is one-half mile. The visibility is the farthest that he can see at that time.

Visibility on runways at airports or jetports is measured with a **transmissometer** (tranz-miss-SOM-uh-ter). Find out how it works. Perhaps someone at your local weather bureau can help you.

Measuring Weather High in the Atmosphere

The instruments that have been described so far are those which are used for observing the atmosphere near the ground. But meteorologists also study the atmosphere higher up, because it too plays a part in making weather on the surface of the earth.

Meteorologists have ways to measure the height of clouds and the speed and direction of winds high above the earth. They also have ways to measure the temperature, relative humidity, and atmospheric pressure of the air at high altitudes. The picture story that begins on page 242 shows and discusses some of the instruments used by meteorologists.

Radar

Radar (RAY-dahr) is used to locate storms and follow their movements closely. Radio waves are sent out from the radar instrument. When the radio waves hit objects such as clouds, the waves are **reflected,** or bounced back. A radar receiver picks up the reflected waves. These reflected waves make a picture on a screen of the objects that have reflected the waves. Some cloud patterns mean that severe storms are coming.

Balloons

Weather stations send balloons filled with a lighter-than-air gas into the atmosphere. As these balloons rise, they are watched carefully with special telescopes. The way they rise or are blown about can tell a meteorologist much about the winds in different layers of the atmosphere. By observing the balloons, the meteorologist can figure out the speeds and directions of high winds.

Using What You Have Learned

1. Hang one thermometer in the sun. Place a second thermometer near it, but place it in the shade. How do the temperatures recorded by the two thermometers differ? Which thermometer gives a more exact reading of the air temperature?

2. Measure the exact distances to certain objects from your classroom window. Then keep a visibility record for one week. At the same time each day, note how far you can see.

3. Keep a precipitation record. You will need a rain gauge. Here is a sample record. Reread the pages describing the rain gauge to refresh your memory.

NOVEMBER

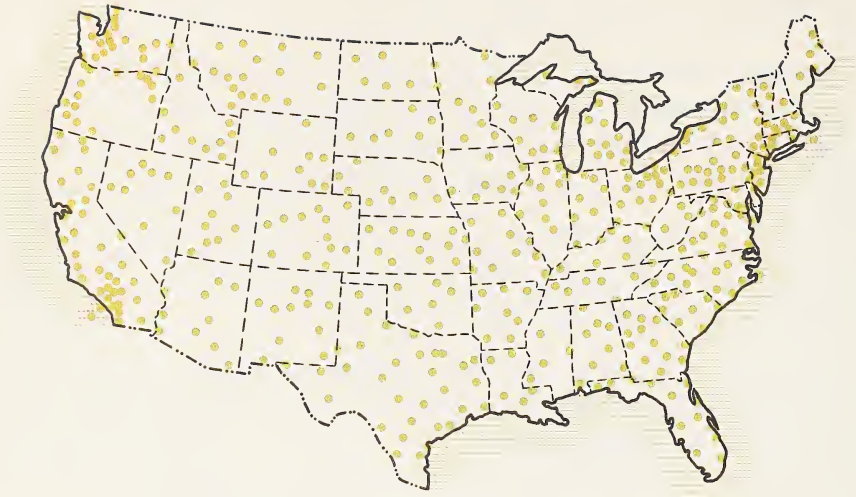
Date	Precipitation
1	.2
2	0
3	0
4	1.4
5	.3
6	0

Weather Maps and Forecasting

One of the jobs of the United States Weather Bureau is to forecast the weather. To make forecasts it works with the Army, Navy, and Air Force and airlines that fly planes all over the United States. It employs a large number of meteorologists to carry on its work. Thousands of volunteers help to keep records of the weather in the places where they live. The weather can be forecast only with the cooperation of many persons. Why is such cooperation necessary?

Making Weather Maps

Some of the weather-observation stations shown on the map on page 238 report every six hours to weather-forecasting centers in the United States. Others report every hour. These reports include information about atmospheric pressure, air temperature, wind speed, wind direction, clouds, visibility, and precipitation. All the stations send out their reports at the same time. The meteorologists in each forecasting center learn from these reports what



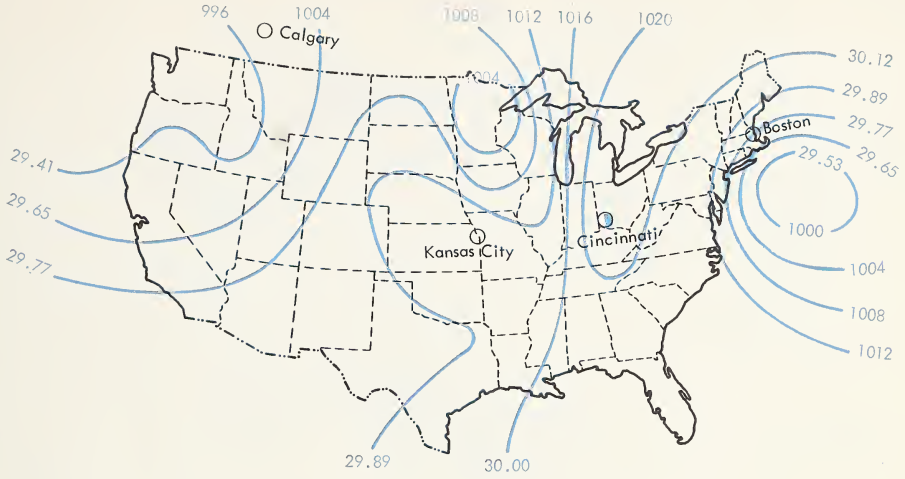
SOME WEATHER-OBSERVATION STATIONS IN THE UNITED STATES

the atmosphere is like in many different places. They record all of this information on large maps of the United States.

First the forecasting expert draws lines on the map to show those places where the atmospheric pressure is the same. These lines are called **isobars** (EYE-suh-bahrz). *Iso* means "equal." *Bar,* as in *barometer,* means "weight." In all places along an isobar, the atmosphere has the same weight, or pressure.

You can see the isobars in color on the map on the next page. Each isobar has two numbers on it. These numbers tell the atmospheric pressure. The smaller number tells what the pressure is in inches of mercury. The larger number gives the pressure in **millibars** (MIL-uh-bahrz). A millibar is another unit for measuring atmospheric pressure.

After the isobars are drawn on a map like the one on the next page, the forecaster can tell the location of the highs and the lows. You can see a high over the Great Lakes extending down through Cincinnati. Look at the isobar marked 30.12 in small numbers. What does this mean? A low was near Boston. Look at the isobar near the center of this low. It is marked 29.53 in the small numbers. What does this mean? Find other highs and lows.



Finding the Air Masses

When the reports come in, the temperature at each station is written on the map. Look at the map shown on page 240. The number in color tells the temperature at each station. Find Moosonee and Sault Ste. Marie. (Moosonee is in northern Ontario, Canada; Sault Ste. Marie is in Ontario on the border between Canada and the United States.) It is 44° F. at Moosonee. What is the temperature at Sault Ste. Marie? What is the temperature at Bismarck, North Dakota? What is the temperature at Minneapolis, Minnesota? The forecaster uses the information about air temperature to locate cold air masses.

The edge of a cold air mass is shown by a line with points on it. The edge of a warm air mass is shown by a line with bumps on it. The points or bumps show the direction in which an air mass is moving. On the map on page 240, find the line that goes from Calgary, Alberta, through Bismarck and then up to Moosonee. The points on the line show that the cold air mass is moving south, further into the United States. How does the forecaster know this? Can you find a cold air mass that is moving from Salt Lake City, Utah, toward Denver, Colorado?

Cold and Warm Fronts

The place where the edges of a warm air mass and a cold air mass meet is called a *front*. A **cold front** is the place where a cold air mass moves forward along the ground and replaces a warm air mass. A **warm front** occurs when a warm air mass moves forward to take the place of a cold air mass. On weather maps the bumps indicate the direction of movement of a warm front. The points of the triangles indicate the direction of movement of a cold front. The map here shows a cold front which goes from Calgary to Bismarck and then north to Moosonee. Can you find a warm front on the map? The front south of Galveston and New Orleans has bumps on one side and points on the other. At the time the map was made, neither the cold nor the warm air mass was moving. This is called a **stationary front.**

Winds, Clouds, and Precipitation

If a weather map is to be useful to the forecaster, there must be a great deal of information on it. It must tell more than just the locations of highs, lows, and air masses. Winds must also be shown. The map must tell where it is cloudy and where it is foggy. The location of rainy and snowy areas must be given. In order to get all this informa-

tion on a weather map, the meteorologist uses signs, or a code. You have already seen one kind of code. You have seen how lines, or isobars, are used to show pressure and how another kind of line is used to show fronts.

The signs on a weather map are explained in a key. By using the key on the map below, see if you can tell what the symbol on the map near Oklahoma City, Oklahoma, means. What kind of weather is there in Oklahoma City? In what direction are the winds blowing? How fast?

Below is a weather map as it would look in a newspaper. Can you answer these questions by studying the map?

1. What is the atmospheric pressure in Galveston, Texas; Seattle, Washington; and New York City?

2. What are the temperature readings in Oklahoma City, Oklahoma; Atlanta, Georgia; and Miami, Florida?

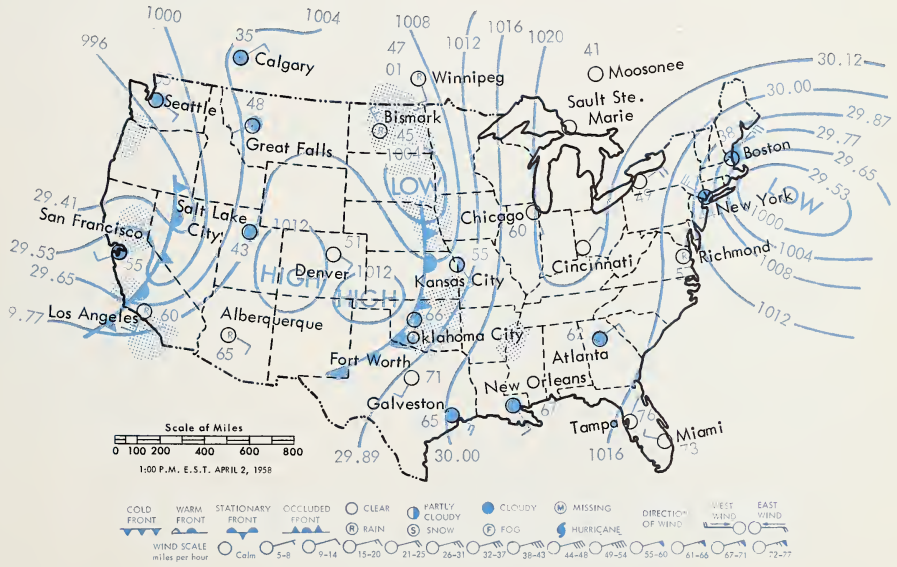
3. What is the sky like in Sault Ste. Marie, Ontario; Fort Worth, Texas; and Tampa, Florida?

4. Where is it raining?

5. How much rain has fallen in Richmond, Virginia?

6. Where is the wind stronger, in San Francisco, California; or Chicago, Illinois?

7. What is the force of the wind at Sault Ste. Marie?



Making a Forecast

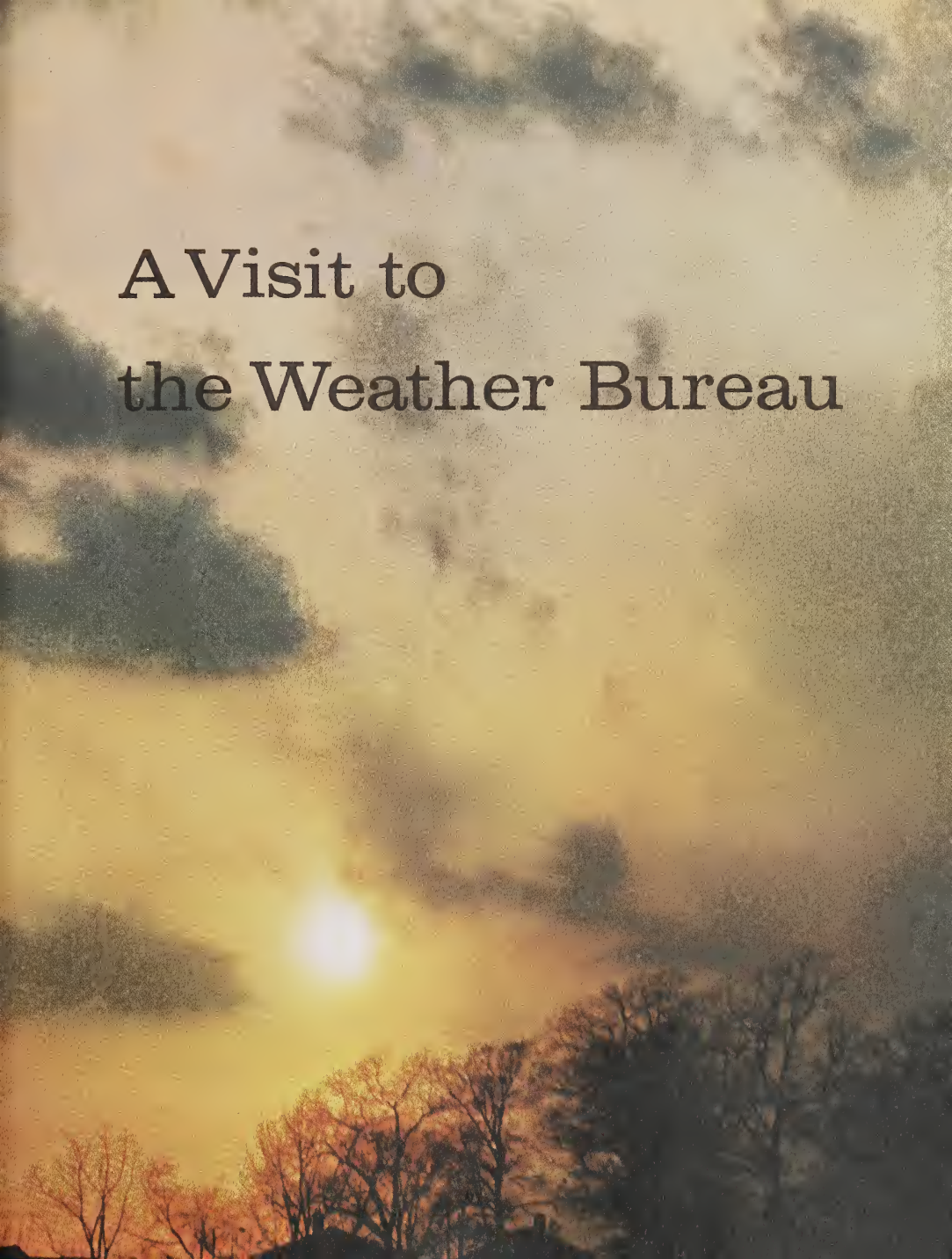
You can tell from a weather map what the weather is like in different parts of the United States. But a map alone does not tell what the weather is going to be like tonight or tomorrow morning. A forecaster needs to know other things to make such predictions. He needs to know how the air masses, and the highs and lows that go along with them, move across the country. He needs to know how fast they move and the general direction in which they move. The forecaster needs to know what kinds of weather go along with highs and lows.

How might a weather forecaster in Cincinnati, Ohio, use the map on page 239? Now it is partly cloudy in Cincinnati. But in all places near the center of the high, skies are clear. How can you tell this from the map? When the high that now has its center at Kansas City reaches Cincinnati, how will Cincinnati's weather change? The weather forecaster can be fairly certain that the skies will be clear in Cincinnati when the high gets there. Highs generally bring clear weather. The forecaster has been charting the movement of this high on his maps every six hours. From his records, he can expect the high to be in Cincinnati in about twelve hours. Now he is ready to make his forecast: "Clear and slightly warmer tomorrow morning."

The expert forecaster knows how high mountains will affect the weather. He has learned about this from his study of meteorology. His records show what it was like in the past when various weather conditions came to his area. Using his past records and his present information, the meteorolgist can forecast correctly nine times out of ten.

ABOUT "A VISIT TO THE WEATHER BUREAU"

The United States Weather Bureau, an agency of the United States Department of Commerce, provides a national weather-reporting service. The bureau also issues forecasts and warnings of weather conditions that may affect the nation's safety and economy. In the next eight pages, you will tour, through pictures and words, two weather bureau offices—one in the center of a large city and the other at a major airport.



A Visit to the Weather Bureau

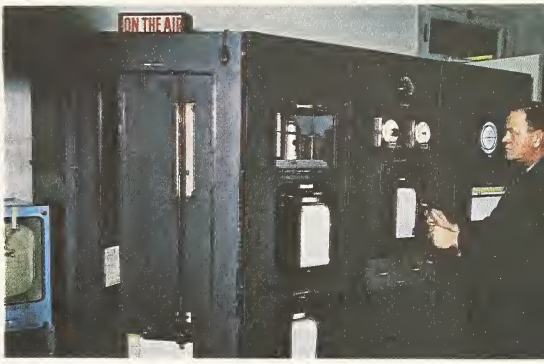
There is much activity in the weather bureau offices. Meteorologists work at their desks, at radar screens, and with special instruments.

There are meteorologists on duty twenty-four hours a day, seven days a week. Meteorologists make observations and record, report, and forecast the weather. Most of the meteorologists' observations are sent to the National Meteorological Center near Washington, D.C. At the Center, experts plot and analyze all the observations made on land, at sea, and in the air. From their maps and charts, meteorologists forecast weather conditions for the next two, three, four, or even five days. Some of the charts are analyzed and forecasts made automatically by high-speed electronic computers.

The radar room is connected to the radar dome on top of the seventy-story building in which this weather bureau is located.

This is the radar room. By watching the radar screen, the meteorologist can locate and identify approaching storms, clouds, and precipitation. From numbers on the outside circle of the screen and from the locations of the dots of light, the meteorologist can find the distances and locations of objects.

There is also a series of instrument racks in the forecast room. These racks contain various gauges and recording devices. Temperature, dew point, wind direction, duration of sunshine, and rate of rain and snow are some of the things measured. In this picture, you see the meteorologist-in-charge looking at the recorder to find the wind speed and direction and the duration of sunshine.



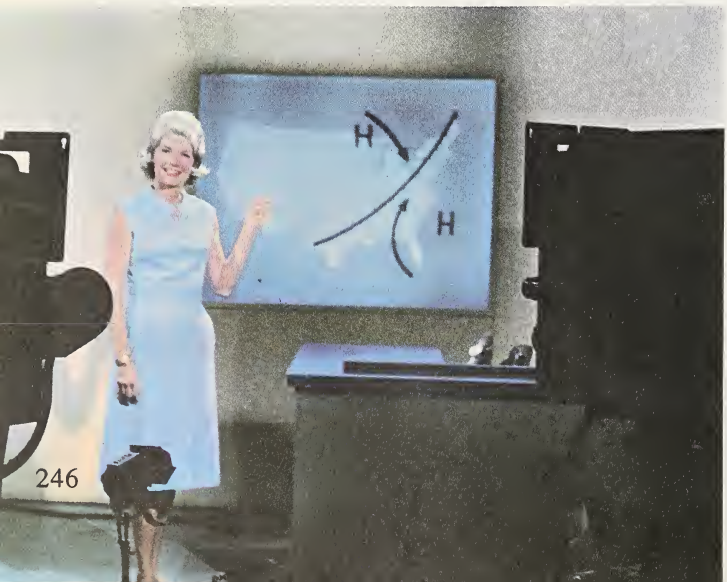
Below is the communication and duplicating room. In this room are many teletype machines, including a local public teletype.

In this room are also national weather teletypes, marine and hurricane teletypes, severe storm warning teletypes, and facsimile machines. There is a telephone information service for the maritime industry. A teletype sends the latest forecast to the telephone girl, who puts the forecast on a tape recording for the automatic public telephone. Because of the duplicating section, the office can rapidly print much information.

Weather forecasts are sent over the office's own broadcasting system.

This is the public room, where the office's daily records are kept. In addition, the bureau maintains weekly, monthly, and yearly records of observations made at all weather bureau offices. State, national, and world records are also maintained. The public room is also equipped to serve as a briefing center for newspaper, television, and radio reporters during severe conditions.

A meteorologist briefs a weather reporter before her television program.



A few hours later, thousands of people see and hear the weather forecast on television. This information will help the people to plan their activities.

The city weather bureau office maintains its services for industry, business, shipping, agriculture, and the public. The weather services for domestic and international aviation are separate. They are handled by the bureau's airport station.

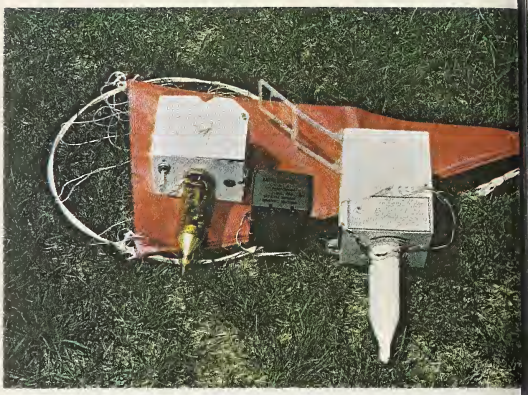
As you can see, the aviation weather station is also a busy, important place.

Teletypes continually receive information from many points in the country.

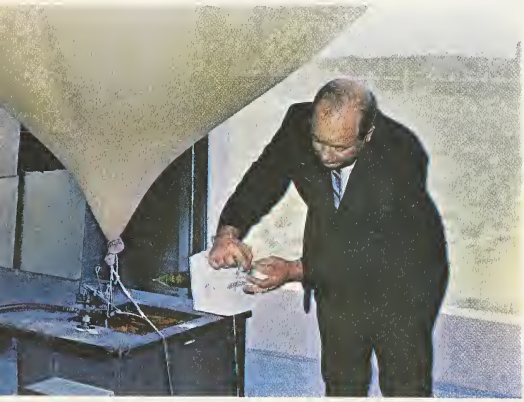
Facsimile machines provide copies of charts from the National Meteorological Center.

A meteorologist checks his observations with the supervising forecaster.

The weather bureau uses over 100,000 sounding balloons. Such balloons are used to carry radiosondes into the upper levels of the atmosphere to measure pressure, temperature, relative humidity, and wind. These data are collected in an area between the surface of the earth and the point where the balloon bursts. Then, the radiosonde parachutes to earth.

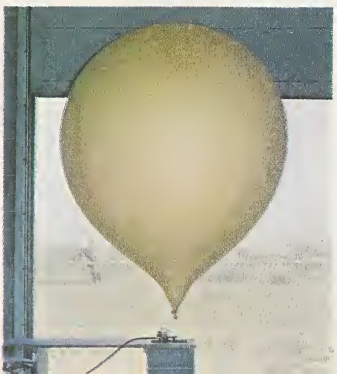


Above is the radiosonde, which has meteorological instruments coupled to a radio transmitter and put in a lightweight box.



A balloon is being inflated with helium, and a radiosonde is being attached.

The balloon, with the attached radiosonde, is released into the air.



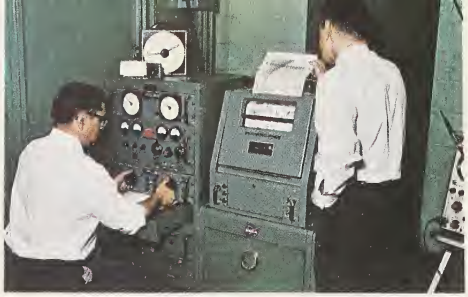
The *Tiros* and other satellites are providing meteorologists with pictures of and data about the atmosphere. This information will greatly aid weather forecasting.

The radiosonde transmits to a ground receiving set. On the ground the data are printed on a recorder chart. The data are studied as the balloon rises higher into the atmosphere. When the balloon reaches the height at which the air pressure inside it is far greater than the outside air pressure, the balloon bursts.

The data from the radiosonde are transmitted over a national teletypewriter system in coded form. Then, various communication systems send the information to all parts of the world. The data are also recorded for use in various weather research projects.

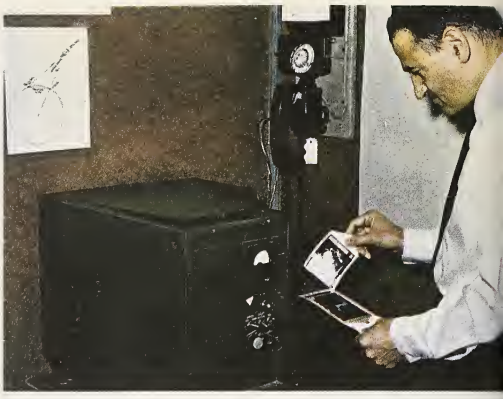
To meet the needs of the Space Age, meteorologists now look to rockets and satellites for data from places in the atmosphere far beyond those reached by radiosonde balloons.

At this station, there is a *Tiros* weather satellite tracking system.

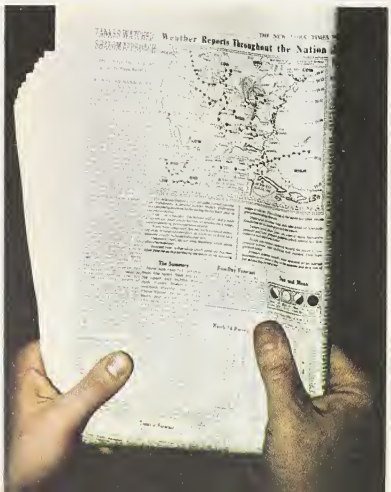


Using the machine, the operator turns the tracker antenna to follow the satellite.

The *Tiros* satellite radios pictures back to earth. Here, you see the supervising forecaster looking at a picture that has just been developed.



A special weather bureau airport office briefs each pilot on general weather conditions and on the kind of weather he may expect on his trip.



The next time you hear a weather report on the radio, see and hear it on television, or read it in your local newspaper, remember that thousands of men and women work day and night to forecast the weather. Forecasts not only help you to plan your daily activities but also help people to protect lives and property.

Weather and the International Geophysical Year

The **International Geophysical Year** (jee-oh-FIZ-ih-k'l), known simply as IGY, which took place during 1957-58, greatly aided meteorologists. For the first time, instruments were placed in satellites that circled the earth. These instruments recorded what it was like in the atmospheric layers and in outer space. Scientists then had better measurements of the sun's rays. They also had measurements of the heat rays that were reflected back into the atmosphere from the earth. Scientists were able to decide more accurately when the earth gained and lost heat. Scientists who were interested in world-wide weather were able to compare measurements recorded by instruments on the satellites with their information about melting ice sheets, temperatures over the oceans, and other weather conditions. Satellites also enabled scientists to spot **hurricanes** (HUR-ih-kaynz), which are very strong storms, early in their formation.

As part of the IGY program, many new weather-observation stations were built. More than 55 new stations were established in Antarctica alone. Before the IGY took place, there were not even enough data on the Southern Hemisphere to allow scientists to draw a weather map. During the IGY, scientists found that the Southern Hemisphere's weather was much colder than scientists had thought it was, except when storms blew in with warm air from the ocean. As a result of the IGY, scientists learned that these storms play a very big part in the making of the weather in this area.

Perhaps the most important information gained during the IGY was that the atmosphere contains a fixed amount of air, which gains heat in some places and loses it in others.

Weather Satellites

Weather scientists are now receiving pictures, taken in space, of the earth's clouds. These pictures are taken by weather satellites and sent back to earth by television.

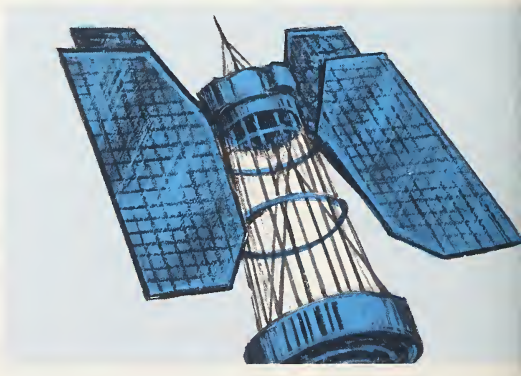
Tiros I was the first United States "Weather Eye" satellite to be sent into space. This satellite was the first weather station to be placed in orbit. Two television cameras sent back pictures of the earth's cloud cover to weather stations on the ground. The cloud-cover pictures helped meteorologists to understand and forecast the weather better.

Tiros III gave scientists the first picture of a hurricane as seen from space.

INTERNATIONAL SCIENCE PROGRAMS

During the IGY program scientists observed weather conditions in many parts of the world. On the left, a scientist studies the inside of a cave formed by the wind and the movement of ice. Below, a scientist reads a gravimeter to study the composition of the earth's crust beneath the ice. At the bottom of the page, you see an explosion made to determine the thickness of ice. How are such explosions used to make measurements?

An outgrowth of the IGY program was the International Years of the Quiet Sun (IQSY). IQSY's goal was to compare data gathered during the sun's quiet period with those from the IGY, in 1957-58, when solar activity was at its highest level since planned scientific observations began, 200 years ago. Above, the sun's quiet period (1954) is shown at the left. The middle view shows the sun during the active period in 1958. Above right is a view taken in 1964 showing the sun in its quiet period again.



Several *Tiros* satellites now circle the earth collecting information about weather conditions.

There are now several Tiros satellites circling the earth and "keeping an eye" on the weather. A later weather satellite called Nimbus has also been sent into orbit to televise changing weather conditions and transmit these data back to central weather-forecasting stations.

Machines to Predict Weather

Meteorologists now use mathematics to forecast patterns of atmospheric pressure. Their method is known as "numerical weather prediction."

Electronic machines known as **computers** (kum-PYOO-terz) are "fed" information about the weather. These computers use this information to develop prediction charts. Many of these charts are more accurate and more quickly prepared than the charts made by skilled weather forecasters. The charts are used by meteorologists to prepare their final weather forecasts.

Using computers, forecasters can now make forecasts in terms of probability. Perhaps you have heard a forecaster on television or radio predicting a 65 per cent probability of showers in the afternoon in your city. The figure "65" is not the result of a guess. The meteorologist knows what conditions produce rain. He will put into a computer information—about such matters as temperature, dew point, clouds, and time of day—about those days in the past when it has rained in the afternoon. This information is stored in the computer. Then, on a particular day, he will put in information about those conditions on this particular day. The computer makes lightning-fast calculations, involving a comparison of the present conditions with the stored information. The computer will come up with the information that 65 out of 100 days in the past when the present conditions existed your city had rain.

Computers are only as good as the information that is put into them. As weather-data gathering improves and weather statistics are quickly analyzed with the help of computers, forecasts will be made with probabilities that are closer to 100 per cent.

The United States Weather Bureau has a numerical weather-prediction center, which it and the United States Air Force use. The center is part of the National Meteorological Center in Maryland. Forecasts obtained from computers there are sent to forecasting stations throughout the country.

Weather forecasting has advanced rapidly in the past several years. But there are many more advances to come in the years ahead.

PATHFINDERS IN SCIENCE

Robert M. White

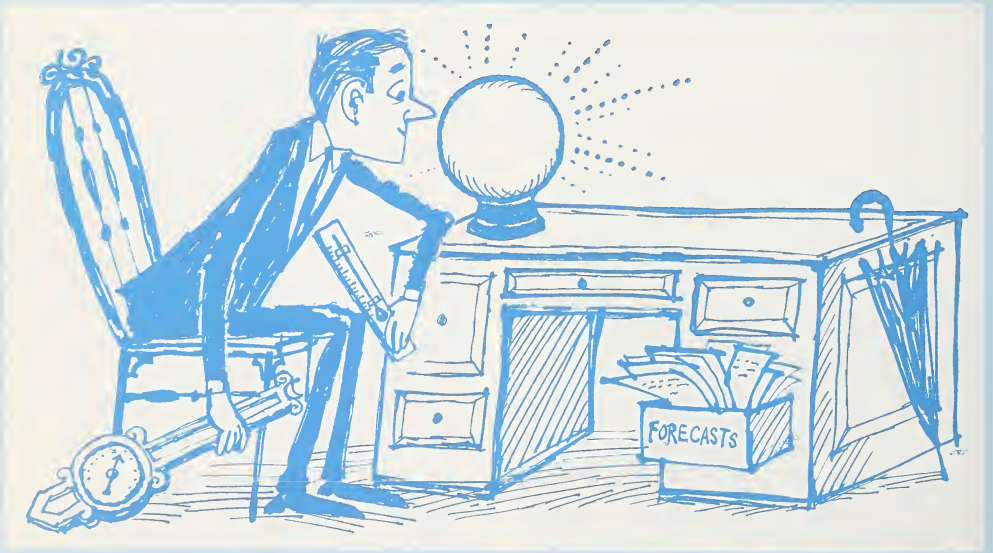
(1923–) United States

Not long ago, cartoonists poked fun at the weatherman by drawing him with a thermometer in one hand and a barometer in the other while he looked through a crystal ball. But the picture has changed. The weatherman is now thought of as a highly trained scientist—a member of a dedicated team of scientists who work day in and day out to serve us.

In charge of this team is Dr. Robert White, who became Chief of the United States Weather Bureau in 1963. Dr. White's preparation for his important post included several years of service as a captain in the meteorological section of the United States Air Force and four years with a weather research center.

As a boy in Boston, Robert White liked to explore the nearby woods, rocks, and waters. He thought he would become a geologist. However, at college he had a chance to work at a weather observatory and decided to become a meteorologist.

In 1959, Dr. White became head of a weather research center. One of his achievements was the development of new ways to broadcast weather forecasts.



How and why did Dr. White change the way forecasts were made? To understand, you must first know something about Dr. White's ideas and beliefs about man and nature.

Dr. White believes that man is still not in control of nature. Man is a part of nature, and so he must find a way to live in harmony with the rest of nature.

It is important for people to act if there is danger in the environment. For example, if there is a chance that a violent storm will occur, not acting can result in much suffering. When hurricane warnings are given in Florida, home and store owners board up windows and doors to prevent injury and breakage. People living near the coasts move to safer places until the storm is over.

Dr. White believes that people listen to warnings from trustworthy sources. He handled the broadcasting of forecasts by having the forecaster say something like this: "The chances of rainfall through tonight are two in ten, rising to five in ten by morning and to ten in ten by tomorrow night." This kind of forecast lets people know the degree of uncertainty of the forecast, as the weatherman himself knows it. When people heard these forecasts, the people took action to save property and lives when there was a likelihood of danger. Since Dr. White became chief of the United States Weather Bureau, many cities in the country have been broadcasting their forecasts this way.

"Meteorology," says Dr. White, "is on the threshold of a true revolution. The forecasts of specific weather that interest us as ordinary people—whether it will rain tomorrow or not—still need a lot of improvement. But a revolution is taking place in forecasting, nonetheless. We have moved in recent years from the era of weather forecasting as an art into a new era of meteorology as an applied science. We've already come a long way in a short time."

Dr. White, a leader in this revolution in meteorology, is well equipped to be one.

Volunteer Weather Observers

Every day over 12,000 voluntary observers record the weather in their parts of the United States. Their work includes measuring rainfall, snowfall, and the high and low temperatures for the day. They record these measurements and mail them to the nearest weather bureau.

The weather bureau uses these records to answer the many requests received from people all over the country who want weather information. The weather records of the volunteers are also used in planning hospitals and schools. Weather records are used as a basis for paying insurance claims, weighing evidence in criminal trials, deciding whether or not to buy land in an area, surveying community airport redevelopment, delivering fuel supplies, selecting which crops to plant, planning vacations, and even for deciding whether or not to air-condition a salesman's car.

Volunteer workers are a great help to the weather bureau. Without the help of these volunteers, many of the weather-information needs of the citizens of the United States would not be met.

Using What You Have Learned

1. If you can find a weather map in a newspaper, you can try forecasting the weather. First examine the weather map. Locate the highs, lows, and fronts. From this information, try to forecast the weather on your own. Now check your forecast with the one that is printed in the paper. Make forecasts for several days. Keep a record of them to see how well you do. Compare your record with the records of some of your classmates.

2. Newspapers print various kinds of weather maps. See how many kinds you can collect. You might write to friends in other areas for weather maps. Compare these maps with

ones from your own area. How does each map show warm and cold fronts? How does each show winds, temperature, and precipitation? How does each show highs and lows?

3. Explain why it is very difficult to forecast the weather without knowing what kinds of weather the other parts of the country are having.

4. Make a poster to show cold air masses, warm air masses, a cold front, and a warm front. On your poster show the kinds of weather in a cold air mass and a warm air mass. Then show the kinds of weather along a cold front and along a warm front. Put the poster on a wall in your classroom. When there is a change in the weather where you live, use your poster to explain whether it was caused by a cold front or a warm front moving into your locality.

5. If you want to learn the meanings of the weather symbols given on the map on page 241, here is a good way to do so. Draw each symbol on a small card. Include those symbols that stand for the different wind speeds. On the back of each card, write the meaning of the symbol. See how many symbols you can understand without looking at the backs of the cards.

6. You or a group of pupils may want to act as meteorologists for your class. You can set up a weather station. To do this, you will need the following instruments:

thermometer
barometer
cloud charts
wind vane
visibility chart
air-speed chart, or anemometer
wet-bulb and dry-bulb thermometers or a hair hygrometer
rain gauge

Decide at what times you will make your observations and how you will keep your records.

WHAT YOU KNOW ABOUT

Probing the Atmosphere

What You Have Learned

The air around the earth is called the **atmosphere.** The atmosphere is divided into five layers: the **troposphere,** the **tropopause,** the **stratosphere,** the **ionosphere,** and the **exosphere.** Weather takes place in the atmosphere near the earth. Weather scientists, or **meteorologists,** forecast weather by using **thermographs** to measure air temperature and **barometers** to measure **atmospheric pressure.** Other instruments used in weather forecasting are **wind vanes, rain gauges, transmissometers,** and **anemometers. Radar,** weather balloons, **radiosondes,** satellites, and **computers** are also used. The United States Weather Bureau has a numerical forecasting center that uses computers to develop prediction charts. These charts are sent to forecasting stations throughout the country. The charts are more accurate than charts made by skilled weathermen.

Meteorologists observe the clouds to obtain information about the weather. Clouds provide much information about weather changes. A cloud forms when water evaporates into the atmosphere and becomes water vapor. Air is constantly moving, and some of that movement is upward. The air becomes cooler away from the earth. Some of the water vapor changes back into liquid. It is then called a cloud. **Cumulus clouds** may indicate wind, driving rain, hail, or tornadoes. **Cirrus clouds** may mean bad weather is ahead. **Stratus clouds** mean that it will soon rain.

Thousands of meteorologists using many kinds of instruments work day and night to forecast the weather. Volunteer observers help the weather bureau keep weather records of every section of our country.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

anemometer	jet stream	radiosonde
atmospheric pressure	meteorologist	relative humidity
computer	millibar	stratosphere
hygrometer	precipitation	tropopause
isobar	radar	troposphere

Name the Layer

Write the numbers 1 to 7 in your notebook. Next to each number write the layer of the atmosphere described in each sentence below.

1. The layer in which there is almost no weather.
2. The layer in which weather takes place.
3. The highest layer of the earth's atmosphere.
4. Nearly all winds and clouds are found in this layer.
5. Wind currents in this layer are called jet streams.
6. This layer is above the stratosphere.
7. Jet pilots like to fly in this layer.

Tell the Difference

1. highs—lows
2. maximum thermometer—minimum thermometer
3. troposphere—tropopause
4. cirrus clouds—cumulus clouds
5. isobars—millibars
6. cold front—warm front

YOU CAN LEARN MORE ABOUT

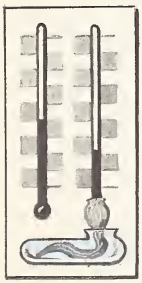
Probing the Atmosphere

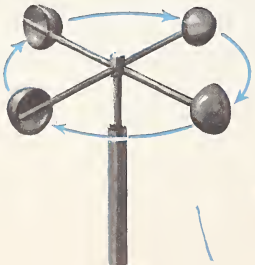
Name the Clouds

What kinds of clouds do you see in the picture?

Can You Tell?

How do the instruments below help the meteorologist predict the weather?

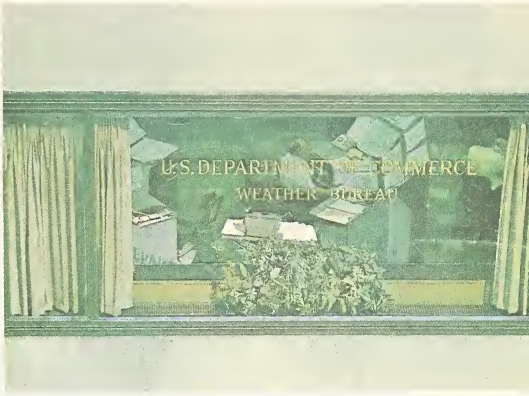




You Can Visit

A weather station is a fascinating place to visit. Perhaps there is a United States Weather Bureau office near your home. At a weather station you will see meteorologists at work. And you will see many of their instruments.

Look again at the pictures of the United States Weather Bureau in action on pages 243 to 250. How is the weather station you visit like the one in the pictures? How is it different?



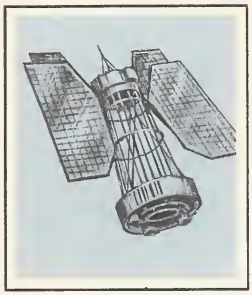
You Can Read

1. *Hurricanes, Tornadoes, and Blizzards,* by Kathryn Hitte. Introduces some basic principles of air and winds. Explains how, why, and where violent storms take place.
2. *Exploring the Air Ocean,* by Frank Forrester. A history of the science of meteorology.
3. *The Wonderful World of the Air,* by James Fisher. Very well illustrated story of the atmosphere.
4. *Weathercraft,* by Athelstan F. Spilhaus. A guide to making a home weather station.
5. *Our Changing Weather,* by Carroll and Mildred Fenton. Shows how meteorologists forecast the weather and gives hints on how you can make forecasts.

8

Probing Outer Space

The Challenge of Outer Space
Rockets Explore Space
Men Venture into Space



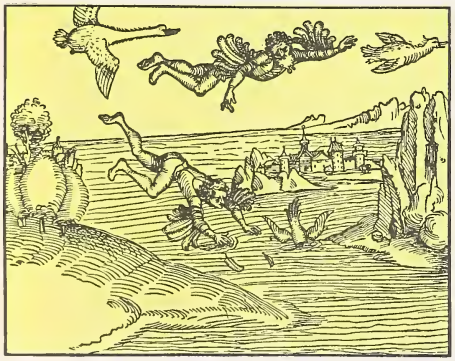
Why do men want to explore space? How many reasons can you think of? Do you think that perhaps one of the reasons is that men are curious to find out what is in space? Curiosity is the desire to find out. Curiosity often leads men to experiment, to discover, and to invent. Curiosity is the key to finding out.

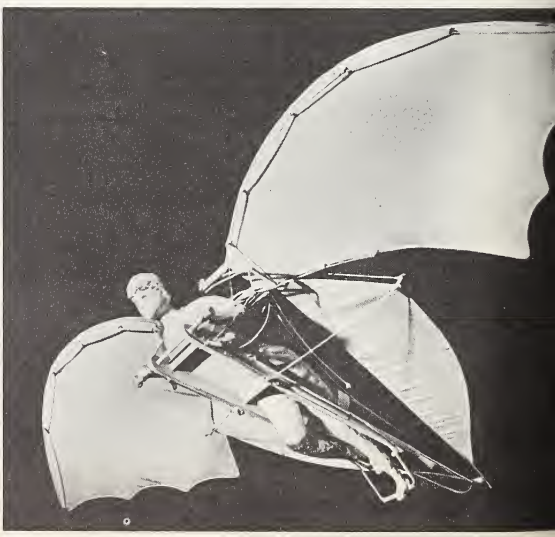
The Challenge of Outer Space

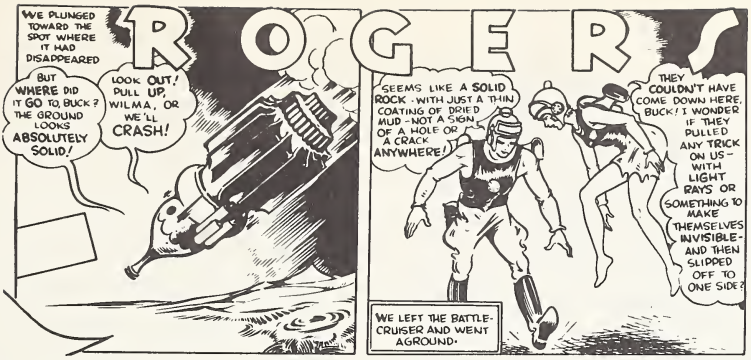
Curiosity has led men to discover methods of preventing and treating disease. It has led them to find new ways in which to harness the energy of the sun. It has made their everyday living safer and more comfortable. And now the desire to find out more about the universe has led men into space.

Men hope to reach the moon and the planets someday. How soon depends on how quickly scientists solve many problems. Scientists must first discover how to keep men alive in space. In this unit, you will learn about this and other problems that scientists must solve before men can reach the moon.

Man has long dreamed of flying. A Greek myth tells of Daedalus and Icarus, who used wings made of wax and feathers to try to fly. At the right is a flying machine designed by Leonardo da Vinci in 1500. Find out about early attempts to fly.






ROGERS
WE PLUNGED TOWARD THE SPOT WHERE IT HAD DISAPPEARED
BUT WHERE DID IT GO TO, BUCK? THE GROUND LOOKS ABSOLUTELY SOLID!
LOOK OUT! PULL UP, WILMA, OR WE'LL CRASH!
SEEMS LIKE A SOLID ROCK - WITH JUST A THIN COATING OF DRIED MUD - NOT A SIGN OF A HOLE OR A CRACK ANYWHERE!
THEY COULDN'T HAVE COME DOWN HERE, BUCK! I WONDER IF THEY PULLED ANY TRICK ON US - WITH LIGHT RAYS OR SOMETHING TO MAKE THEMSELVES INVISIBLE - AND THEN SLIPPED OFF TO ONE SIDE?
WE LEFT THE BATTLE-CRUISER AND WENT AGROUND.

In 1929 space travel was science fiction. Today we are only a few years away from the time when men will land on the moon and possibly Mars and other planets.

For ages men have dreamed of traveling to the moon and to the planets. But it is only since the development of powerful rockets that man has been able to soar beyond the earth's atmosphere.

The first questions man had about space had to do with the atmosphere: Is all the space between the earth, the moon, and the stars filled with air? Is the air above the earth cold or hot? The first space explorers had to answer many questions like these. But long before real explorations were possible, voyagers in story and legend traveled into space on giant birds and in spacecraft. Look at the pictures above from a popular cartoon strip called "Buck Rogers in the 25th Century." This comic strip first appeared in 1929, when most men thought space exploration impossible. Stories such as these entertain readers and make them more curious.

Balloons in the Air

While some dreamed of space travel, others took the first steps toward exploring space.

By 1783, the Montgolfier (mon-gol-fee-AY) brothers of France had built a huge balloon of paper and linen. One day, a man climbed into the **gondola** (GON-duh-luh) below this balloon. Other men built a fire below the open balloon. The air inside became hot. Many people thought the balloon would burn. Instead, it slowly rose into the air, carrying the balloonist many feet above the earth.

Can you explain why the balloon floated into the atmosphere? Would the warm air in the balloon have more or less weight than the same amount of air outside the balloon?

Not everyone was satisfied with hot-air balloons. The fires were dangerous,

and sometimes the balloons burned. Those that did rise remained in the air for only a short time. When the air in the balloon cooled, the balloon returned to earth. Unheated air was too heavy to keep the balloon in the air.

Scientists searched for lighter gases to use in balloons. Nitrogen and oxygen, the main gases in the atmosphere, were much too heavy. Finally, it was decided to use hydrogen, the lightest known gas. Hydrogen is only one-fourteenth the weight of air.

Balloons filled with hydrogen floated higher into the atmosphere. These balloons could be controlled by releasing some of the gas. Can you tell how?

Exploring in Balloons

As balloons went higher, men asked questions about traveling above the earth: What happens to a man's body in a floating balloon? How does the atmosphere above the earth compare with air near the ground? No one knew, but some men started to find out.

On a January morning in 1793, people in Philadelphia watched the first balloon in the United States rise to 5,000 feet. The pilot of the balloon made a few tests for some scientists. One medical doctor wanted to know if the air at 5,000 feet is different from the air on the

ground. When the pilot reached that altitude, he filled bottles with air and brought them back to the doctor for study.

Another medical doctor wished to find out if altitude affects the rate of heartbeat. The pilot tested his own pulse at 5,000 feet. He had a pulse rate of 92 times a minute. On the ground, the rate had been 84 a minute. Was it the altitude that affected his heartbeat? Or was it the excitement of the flight? What do you think?

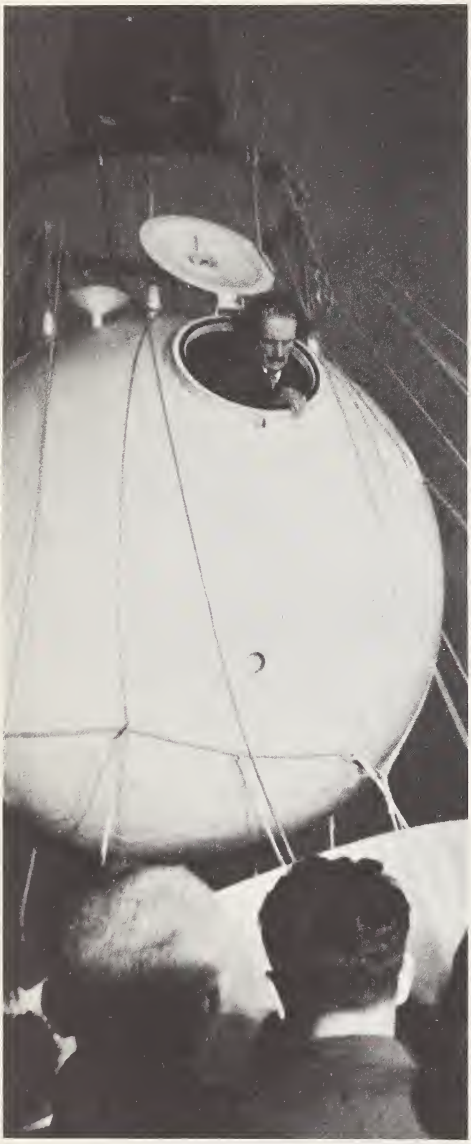
Balloon flights continued, and scientists wanted answers to other questions. How high could a man rise in an open balloon? In what ways does air temperature change as altitude increases? People had long known that it is cold on top of high mountains and that the air is very thin. Scientists believed that the atmosphere became colder as altitude increased. Was this really so? The only way to find out was to rise even higher.

In 1875, three men in an open gondola reached 25,000 feet—much higher than anyone had gone before. The men kept records as the balloon climbed. On the ground, the air temperature was 70 degrees. As the balloon rose, the air became colder. The balloonists found that the temperature dropped about 1 degree for each 300 feet of altitude. Using this information find what the air temperature was at 24,000 feet.

As the balloonists went higher, they became very sick. One of them managed to open the control valve, and the balloon started down. None of the men lived to tell what had happened, but their records were recovered. From these records, scientists learned that the explorers had suffered from cold and from lack of oxygen. These records helped scientists to prepare for higher flights.

In 1927, an American balloonist, Captain H. C. Gray, rose into the stratosphere to 44,000 feet. As he rose, he took careful temperature measurements. At 31,000 feet, he found that the temperature was 32 degrees below zero. At 40,000 feet, it was 28 degrees below zero. It seemed that, as the altitude increased above 31,000 feet, the air became warmer. This new evidence puzzled scientists. They had believed that the air would steadily become colder, but now they were not sure.

More flights were made. Again, a warmer layer of air was found at about 40,000 feet. But above that level, the temperature became colder and colder. Now scientists had a better idea of temperature in the atmosphere high above the earth.



Auguste Piccard prepares to close the lid on the gondola of his balloon and rise into the air.

Exploring the Stratosphere

Men were still a long way from reaching outer space. They had explored far above the earth and learned many new things, but these flights were dangerous. There were too many problems—intense cold, lack of oxygen, frozen instruments. They could go no higher in open balloons.

In 1931, a Swiss scientist named Auguste Piccard (pee-KAHR) invented a special closed gondola which solved these problems. It was shaped like a ball and was very light. Windows were placed in the walls. Inside the ball were tanks of air and scientific instruments. The balloonist also carried a camera. In this closed gondola, Professor Piccard rose to a record altitude, 51,000 feet. However, he was not satisfied. He built a better gondola and rose still higher.

Piccard was interested in **cosmic rays** (KOZ-mik). Cosmic rays are high-speed atomic particles that come from outer space. Scientists knew that these rays might be harmful, but they did not know much about the rays themselves. How strong are cosmic rays in space? Would they be dangerous to man?

To find out about these rays, Piccard performed an experiment. He used a special photographic film to gather evi-

dence. Each particle hitting the film would make a streak on it. Piccard prepared two film packages. He left one on the ground. The other he carried into the thin air of the stratosphere. Why did Piccard leave one package on the ground?

After the flight, he compared the two film packages. The film from the stratosphere had been streaked many times. The film from the ground had few streaks. Why? Piccard hypothesized that the atmosphere blocks the cosmic rays before they reach the surface of the earth. But in space, where the air is very thin, these rays are much more numerous. In space, cosmic rays might be very dangerous to living things.

To the Edge of Space

After Piccard's flights, other balloonists flew higher and higher in closed gondolas. New experiments were performed on each flight. For example, scientists wanted to know if tiny plants and insects could live after being exposed to strong cosmic rays. To find out, a balloon carrying some plants and flies rose to 72,000 feet. The plants returned unharmed, but the insects did not survive. Before they died, however, they laid eggs. Later, these eggs hatched into normal, healthy insects.

Auguste Piccard's balloon. Where is the gondola attached to the balloon?

On this flight, too, scientists discovered that high in the stratosphere, where the cold is intense, bacteria live in the air. Bacteria are too small to be seen by the eye alone. How do you think the scientists found evidence of bacteria in the stratosphere?

Next, to learn more about cosmic rays, scientists decided to send animals on balloon flights. Four monkeys, named Eenie, Meenie, Minie, and Mo, took part in an important experiment. The monkeys were placed in a gondola designed to shield them from cosmic rays. Would the gondola block the rays? Would the monkeys be protected? To find the answer, a piece of special film was attached to each monkey.

The balloon rose to a height of 121,000 feet. The monkeys remained aloft for 29 hours. Finally, the gondola returned to earth by parachute. When the film was inspected, few streaks were found. The shield had protected the monkeys. For a long time, the monkeys were carefully observed. They remained healthy and were given a good home in a zoo.

With balloons, scientists were able to explore far into the unknown skies. They spent many long, difficult hours making observations and keeping records in their floating laboratories high above the earth. Bit by bit they gathered important information about temperatures, cosmic rays, and other conditions in space. Science was no longer earthbound. The pathway to space was open.

Using What You Have Learned

1. Make a chart showing famous balloon flights and the altitudes reached.

2. Visit a weather station that launches weather balloons. Watch a balloon being launched. Find out how the balloon sends back information about conditions in the air.

3. Watch for an Echo balloon in orbit. Write to the National Aeronautics and Space Administration, Washington, D.C., 20546, for information about when it can be seen. You may also find a schedule in your local newspaper. Keep a record of the times you see it.

4. Modern balloons do not use hydrogen gas for high-altitude exploration. Their gas bags are made of a special material. Find out about modern balloons in an encyclopedia.

5. Read the Jules Verne novel, *Around the World in Eighty Days*. It tells of an imaginary balloon trip made long ago.

Rockets Explore Space

Today we live in the Space Age. **Rockets** (ROK-its) lift men into outer space. Rockets also carry small spacecraft in their noses. When a rocket reaches the top of its flight, it may fire the spacecraft into orbit. An orbit is a path around a body. When a spacecraft goes into orbit, the spacecraft is called a **satellite** (SAT-uh-lyt). Today many satellites are orbiting the earth. Spacecraft have been sent to the moon and have probed areas millions of miles from the earth, where no man has traveled. Rocket power has freed men from the powerful pull of gravity that kept them from exploring space.

Rockets such as those on the left carry satellites like the one on the right into space. Satellites are attached to the nose sections of rockets and are fired into space at great speeds by the rockets. The satellite you see below is the *Early Bird* satellite. What can you find out about this satellite?

What do you feel with the hand on top of the balloon when the air rushes out? What happens when you throw a basketball forward while wearing roller skates?

Rocket Engines

How does a rocket engine work? The idea is very simple. You can find out for yourself.

Blow up a balloon. Rest the top against your hand as the air rushes out. You know the air is rushing out of the balloon because the balloon becomes smaller. Do you feel the balloon pushing back against your hand? As the air rushes out from the open end, you can feel the balloon pushing upward.

Try this when you go roller skating. While standing on your skates, throw a basketball forward. Of course, be careful where you throw it. What happens? As you throw the ball forward, you roll backward. Why? You know force is needed to move an object. When you apply a force to the ball, you set it in motion. A force also pushes on your body. You move—in the opposite direction.

Why do you roll backward? About 1680, the great English scientist Isaac Newton discovered that for every force in one direction there is an equal force in the opposite direction. This is known as Newton's **Third Law of Motion.** Perhaps you have heard it said this way: *For every action (force) there is an equal reaction (opposite force).*

Try the following experiment to find out more about Newton's Third Law.

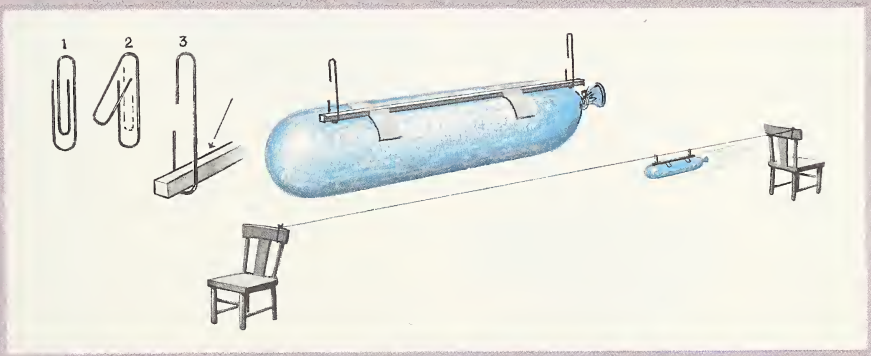
Is There an Equal and Opposite Force for Every Force?

What You Will Need

masking tape
long balloons
wire
paper clips
balsa stick (¼-inch square and 12 inches long)
25 feet of nylon sewing thread
2 chairs

How You Can Find Out

1. Stretch the thread tightly between the chairs.
2. Make two hooks out of paper clips as shown in the diagram. Mount the hooks at each end of the stick.
3. Blow up one balloon and hold the end tightly so no air leaks out.
4. Tape the balloon to the stick as shown.
5. Carefully slip the hooks over the thread.
6. Let the balloon go and release the air from it without shaking the stick or thread.



Questions to Think About

1. Measure the distance the stick traveled. What was it?
2. Does it travel the same distance a second time?
3. Keep a record of your experiments with two balloons. What does your record show?

Use Newton's Third Law of Motion to explain what is happening in each picture.

The air pushing out of the neck of the balloon produced a force. The stick was pushed a specific distance by an opposite force. This force was the **reaction.** Can you think of a simple way to double this force? Can you predict how far the stick will travel when the force is doubled? Design an activity to test your ideas. You can make accurate comparisons if you make careful distance measurements.

From these experiments you can see that when more balloons are added, the stick will travel a greater distance.

Newton's Third Law helps to explain how rocket engines work. Their operation depends on the **action-reaction** principle.

Rocket engines have two main parts. Fuels burn in the **firing chamber.** The hot gases produced by the fuels rush out the **exhaust nozzle.** These gases have great force. When the rocket is on the launching pad, as in the picture on page 276, the gases push downward. What happens to the rocket?

More Power for Rockets

Rockets need powerful engines. Without this power, rockets would never leave the earth. They would be held on the ground by the force of gravity.

You can measure the pull of gravity by measuring the weight of an object. You can also learn about the force needed to overcome this downward pull. To move objects away from the earth, an upward force is needed. How much?

Rockets that carry men into space are very heavy. At launching time, manned

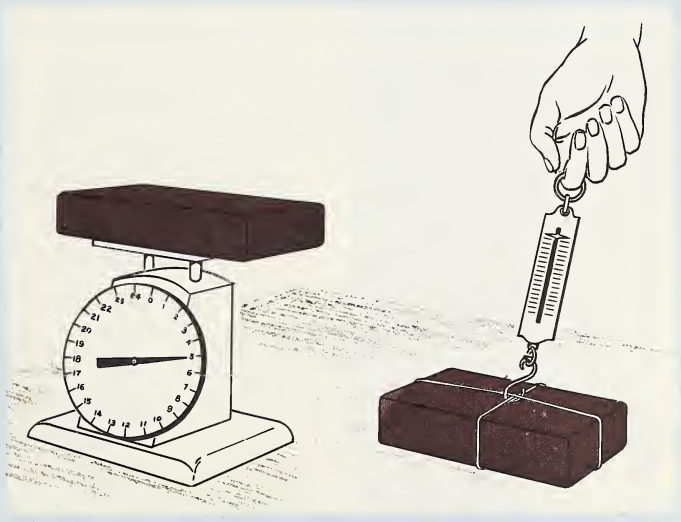
How Much Upward Force Is Needed to Move Objects Away from the Earth?

What You Will Need

kitchen scale
brick
spring scale
string

How You Can Find Out

1. Weigh the brick on the kitchen scale. It will probably weigh about 5 pounds.
2. Tie a string around the brick so that it will not slip off.
3. Attach the spring scale to the string. Watch the pointer.
4. Lift the scale slowly and smoothly until the brick is off the floor.



Questions to Think About

1. How much pull was shown on the spring scale?
2. You probably expected to see a pull of about 5 pounds. Instead, you needed somewhat more than a 5-pound pull. What does this show?

As the amount of exhaust gas or its speed through the exhaust nozzle becomes greater, the thrust of the rocket will increase.

rockets may weigh more than 200,000 pounds. A great force is necessary to lift such mighty loads. Scientists have learned that the force should be at least one and one-half times the weight of the rocket. Can you figure the force?

Thrust

The force of a rocket engine is called the **thrust.** To increase the power of a rocket engine, more thrust must be provided. Scientists know two ways in which to do this. The experiment on the next page will help you learn one way to increase thrust. Stop and do the experiment now. Your experiment will show you that two balloons deliver more thrust than one. A greater amount of air is forced out of the balloons. The reaction, too, has greater force.

If the first launching was successful, the car was pushed along the floor. As long as the air was being forced out of the neck of the balloon, an opposite force kept pushing the car.

The car can be made to go farther and faster. To do this, you will need more thrust. You can use the same balloon. Would the thrust be different if you changed the size of the hole? Design an experiment to test your ideas. Take careful measurements of the distances traveled so that you can make

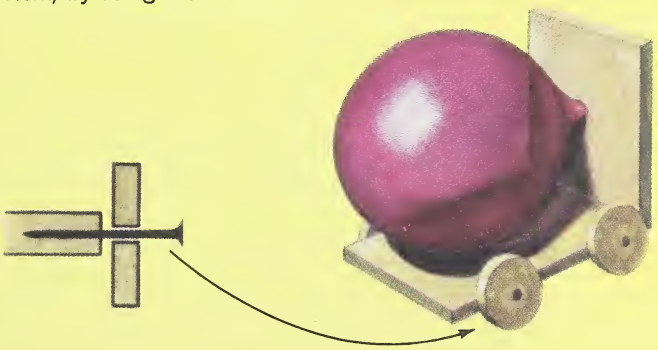
How Can Thrust Be Increased?

What You Will Need

2 balloons
4 small wheels
2 pieces of balsa wood (¼ by 2 by 3 inches for the back, and ¼ by 2 by 4 inches for the base)
pins
4 nails
string (18 inches)

How You Can Find Out

1. Mount the wheels on the base as shown. They should turn easily.
2. Drill a small hole (about ⅜ of an inch) in the back piece.
3. Pull the neck of one balloon through the hole.
4. Pin the back on the base.
5. Tie the ends of the string together, and put it around the middle of the balloon.
6. Blow up the balloon until it just fits the string.
7. Pinch the end of the balloon with your fingers, and make sure no air escapes. Remove the string.
8. Place the car on the floor carefully, and let the balloon go.
9. Next, try using two balloons.



Questions to Think About

1. What was the distance the car traveled? Repeat the activity, and record the results of each test.
2. What made the car move?
3. What happens when you use two balloons?

comparisons. Did the size of the hole make a difference?

Thrust depends on two things—the amount of a substance that passes out of the exhaust nozzle, and the speed at which the substance is traveling. Thrust increases as the amount or speed of exhaust through the nozzle increases.

To gain thrust, rocket engines use special fuels. When these fuels burn in the firing chamber, expanding gases blast out of the nozzle. The greater the number of gas molecules leaving the engine and the greater the speed, the greater the thrust. Some fuels have been developed that release greater amounts of energy than fuels now being used in rockets. You can change the thrust of your balloon rocket by using more or less air. Design an experiment to test the effect of using strings of various lengths.

Thrust can be increased in another way. One part of the exhaust nozzle is made with a smaller opening. When the hot gases rush past this narrow opening, their speed is increased. You can see this by doing the experiment below.

You know that the pull of gravity must be overcome when rockets blast off for space. As rockets become heavier, more thrust is needed. Engineers have learned how to increase thrust by using high-energy fuels and special exhaust nozzles. Engineers now have the powerful rockets to explore space.

EXPERIMENT

How Does a Narrow Opening Affect Thrust?

What You Will Need

garden hose attached to water source

How You Can Find Out

1. Remove nozzle from the hose.
2. Turn on the water and notice how it comes out slowly.
3. Place your finger on the opening of the hose to make it smaller.

Questions to Think About

1. What happens to the stream of water when you place your finger on the hose opening?
2. Can you tell why this happens?

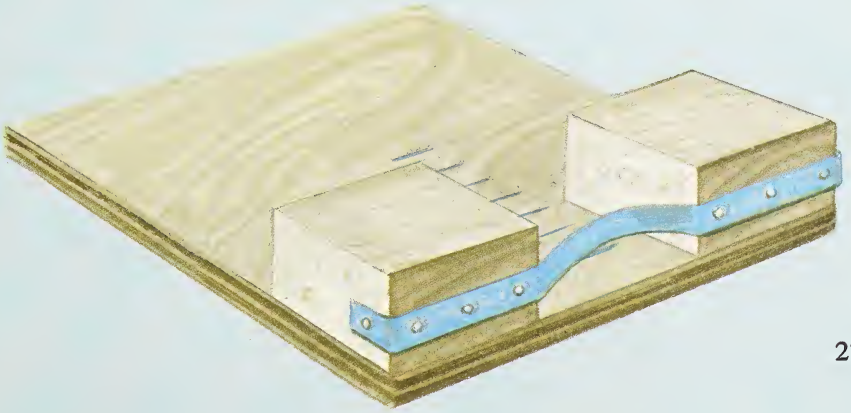
How Is an Object Placed in Orbit?

What You Will Need

plywood (¾ inches by 1 foot square) for base
2 corner blocks (2 by 4 by 4 inches long)
rubber strip (1 by 15 inches) cut from an old tire tube
nails
glue
marbles

How You Can Find Out

1. Spread glue under the corner blocks and nail them into place. Allow several hours for the glue to dry.
2. Place the rubber strip in position. Fold one end, and nail it to a corner block.
3. Nail the other end in position in the same way. When nailed, the rubber strip should be slightly loose.
4. Mark a scale in inches on the center of the base. Mark your measurements from the end of the board.
5. Place the base at the edge of a flat table top.
6. Place a marble in the center of the sling.
7. Hold the base down so that it does not slip.
8. Pull the marble in the sling back to the 2-inch mark.
9. Let the marble go when no one is in the way.
10. See the picture below and then turn to page 280 for the rest of this experiment.



Questions to Think About

1. How far does the marble travel horizontally before it reaches the ground? Measure this from a point directly below the edge of the table. Try this several times, and keep a record of the results.
2. Compare the results. Are they the same?
3. If the results are not the same, can you explain why?

Going into Orbit

"Everything that goes up must come down." In the past, people did not question this statement. Today, we know that it is not true. Just a few years ago, scientists placed many types of spacecraft into orbit around the earth. After a while most of the spacecraft came down, but there are still some orbiting the earth. How would you go about finding out which satellites they are? How long are they expected to stay in orbit?

In the experiment, you found that each time you shot the marble with the rubber sling, the marble started off in a horizontal direction. Over two hundred years ago Isaac Newton studied motion. The result of his studies was his **Laws of Motion.** According to Newton's **First Law of Motion,** the marble should have continued to move at the same speed and in the same direction. Newton's First Law states that *an object at rest remains at rest, or if in motion continues in motion in a straight line and at the same speed, unless an outside force acts on it.* But you saw that the marble changed its direction. It moved in a curved path toward the earth!

The marble moves in two directions. One direction is *horizontal,* or straight out in line with the ground. Once the marble starts to move, no other horizontal force acts on it. Its horizontal rate of speed remains the same. The other direction of the marble is *vertical,* or down. The force of gravity is a *constant* force that keeps pulling the marble down, making it fall faster and faster. This is explained by Newton's **Second Law of Motion,** which says that *the rate at which the speed of an object changes depends on two things: the mass of the object and the force applied to it.* For example, if you push a wagon hard enough it will start to move, and if you apply a constant force, the wagon

will go faster and faster until the friction of the wheels and the resistance of the air act as opposing forces. In the same way as your pushing the wagon, the force of gravity on the marble makes the marble speed up as it falls.

The horizontal and vertical forces on the marble combined to make the marble move in a curved path.

Can you change the shape of the marble's path? When the sling was stretched to the 2-inch mark, the marble traveled a certain horizontal distance. You measured that distance. Can you predict how far it will travel if the sling is stretched twice as far—to the 4-inch mark? How far with the sling stretched to 6 inches?

Enter your *predicted data* on a graph.

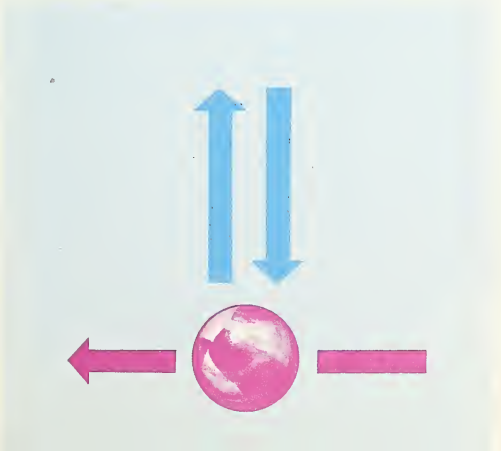
Now test your ideas by experimenting. Make careful measurements. Enter the *experimental data* on the graph. How do your predictions compare with the evidence? If they are not the same, can you explain the differences?

In your experiments, the vertical force on the marble remains the same. The force of gravity makes the marble fall at an increasing rate. It always takes a certain time to reach the floor. For example, suppose the table top is 30 inches high. From that height, the marble will reach the floor in about $\frac{2}{5}$ second. Will this happen each time, no matter how great the horizontal speed?

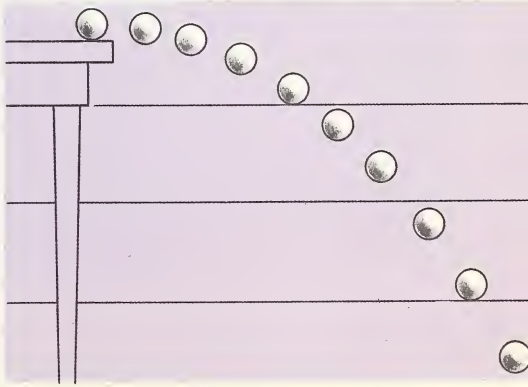
The horizontal force on the marble changes when you pull back farther on the slingshot. When the force is increased, the horizontal speed of the marble increases. The greater the horizontal speed, the farther the marble will travel before reaching the floor.

Does this look something like a picture of the path that the marble took as it was shot by the slingshot?

In what directions does the marble move? What force acts to pull the marble down?



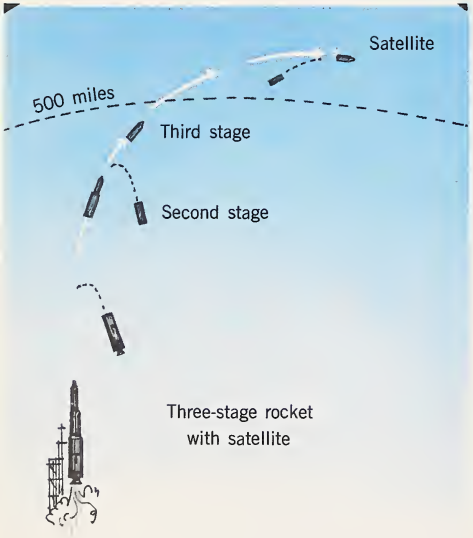
The picture below shows the path the marble took when shot by the slingshot.



What would happen if you could shoot a marble horizontally at a speed of 3 miles a second? Imagine that you are experimenting from a tall tower. Suppose there is nothing in the way and no air friction to slow down the marble. At this speed, the marble would travel horizontally for a great distance, but its path would still be a curve. In a short time, it would strike the ground.

Suppose you were to launch a satellite with a horizontal speed of 5 miles a second. It, too, would travel toward the earth in a curved path. But the earth is also curved, and the pull of gravity is always toward the earth's center. Every 5 miles, the earth curves downward just as much as the satellite would fall downward. The satellite would continue around the earth in a circular path. It would be in orbit, circling the earth every 84 minutes. If there were nothing in the way and no air friction, the satellite would remain in orbit.

Explain why a satellite launched with a horizontal speed of 5 miles a second orbits the earth.



Multistage Rockets

Horizontal speeds of at least 5 miles a second, or 18,000 miles an hour, are needed to place spacecraft in orbit. To reach this speed, scientists often use **multistage rockets.** *Multi* means "many."

A multistage rocket is made up of two or more rockets. The first stage, or first rocket, has the greatest thrust. It boosts the entire load of fuel, instruments, and spacecraft for the first 20 or 30 miles. It also guides the rocket toward a horizontal flight path. When the fuel is burned up, this stage is no longer needed; it can do no more work and is dead weight. The stage is then dropped off.

The second stage is fired. The speed of the rocket increases, and the rocket soars still higher. When the fuel is used up in the second stage, this stage, too, is cast off. Each remaining stage gives extra speed. The rocket goes higher and faster.

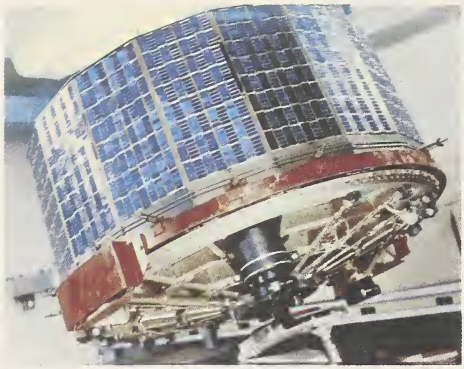
The final stage is fired, and a three-stage spacecraft is now free from its stages. It travels horizontally at 5 miles a second. It will orbit the earth.

Spacecraft remain in orbit as long as their average speed is unchanged. But even 100 miles above the earth, some air is found. As the satellite pushes through this thin air, it is gradually slowed down. Gravity pulls it steadily toward the earth. It orbits lower and lower. When the spacecraft enters the upper atmosphere, the friction of air molecules makes the spacecraft very hot. However, the spacecraft can be controlled so that it will enter the atmosphere more slowly and will not burn.

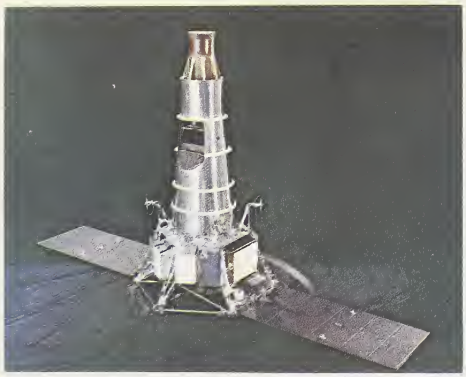
Spacecraft for Special Missions

Spacecraft that orbit the earth are designed for various experiments. American spacecraft are grouped. Below and on the next page are pictures of rockets in each group.

Explorer and *Vanguard* spacecraft collect information about radiation, meteoroids, and temperatures in space. What has been learned so far from these space probes?



Tiros spacecraft carry television cameras to take pictures of clouds.



Ranger spacecraft's television cameras send pictures of the moon back to earth.

Echo spacecraft reflect communications signals and supply data about solar radiation.

PATHFINDERS IN SCIENCE

Robert H. Goddard

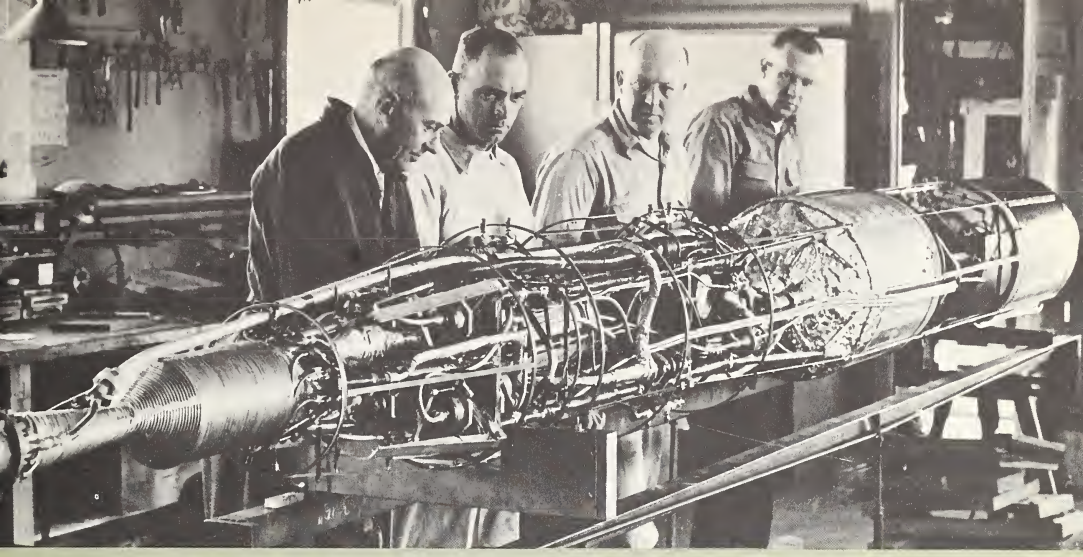
(1882–1945) United States

Some people are able to think far ahead of their own time. They have new ideas and think of new and better ways to do things. But other people are not always able to understand these new ideas. Robert Goddard's ideas were far ahead of his time.

Robert Goddard always dreamed of exploring the skies. As a college student, he decided that rockets would be the best way to travel into outer space. He studied rockets to figure out how they could work better and fly higher. He tested rockets in the basement of a college building. Students laughed at him, and teachers called him a daydreamer. Most people thought rockets were used only to celebrate holidays and to carry signals into the air from the decks of ships. The idea that a rocket could be made powerful enough to go far into the sky seemed silly.

After graduation from college, Dr. Goddard became a teacher at a university, but he continued his research into rockets. More and more people began to believe in his work and offered to help him.

On March 16, 1926, Dr. Goddard tested one of his rockets. He set up the launching frame and placed a four-foot rocket in



Robert Goddard, on the left, is shown assembling one of his rockets.

it. A flaming torch, called a blowtorch, was touched to the combustion chamber. Dr. Goddard pulled a cord. The rocket roared and flamed. It began to rise slowly and then, with increasing speed, jumped into the air. The test flight was a success! The first liquid-fuel rocket had been launched. It traveled 60 miles an hour and went 200 feet into the air.

Three years later, Dr. Goddard launched a rocket that soared twice as high as the first one. But many people who read the newspaper reports did not think of the professor as a real scientist. They thought of him as a man who played with rockets, the way children play with firecrackers.

Dr. Goddard was discouraged and did not have much money left for his tests. But Charles A. Lindbergh, the first pilot to fly a plane alone across the Atlantic Ocean, was convinced of the importance of Dr. Goddard's work. With his help, Dr. Goddard was able to give up teaching and spend all his time on rocket research.

Dr. Goddard was the first to see the importance of placing instruments in his rockets. One of his first rockets carried a barometer, a thermometer, and, most important, a camera to record the readings on these instruments. By 1935, Dr. Goddard's rockets reached heights of over a mile and traveled 550 miles an hour.

Today, rockets soar far into space. Dr. Goddard's faith in himself and his ideas made possible today's exciting probes into outer space.

Space Probes

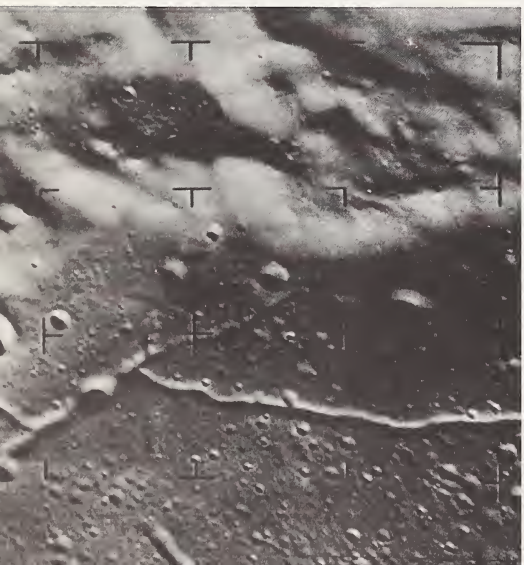
Spacecraft that explore into space are called **space probes.** To launch a space probe, powerful engines boost its horizontal speed to about 7 miles a second. This is the **escape speed** from the earth. At this speed, spacecraft escape from the earth. The earth's gravity slows the probe, but the probe never falls back to earth. Instead, it enters a region in space where the gravity of other objects in the solar system is stronger than the earth's gravity. Then the probe may go into a new orbit and circle the moon, the sun, or another planet.

The United States and Russia have launched **deep space probes.** Some of these probes have explored the moon. Evidence gathered by them shows that the moon has no air and probably does not have a magnetic field like the earth has.

Some probes have been launched far into space. They will never return to earth. Instead, they will go into orbit around the sun. There, they will become new, man-made members of the solar system.

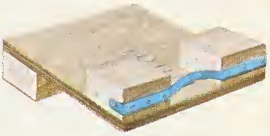
The instruments carried in spacecraft have brought men new knowledge about the earth and space beyond it. Exploring with spacecraft is a great dream come true. It has also prepared men for the greatest adventure of all time—space travel.

Ranger IX spacecraft took a photograph of the moon on March 24, 1965, from 115 miles away.



In July 1965 the first close-up photographs of Mars were taken by the *Mariner IV* satellite.

Using What You have Learned



1. You have learned about paths taken by an object that is launched *horizontally*. Are the paths the same if the object is launched at an *angle?* Set up your rubber sling apparatus as shown in the sketch. Repeat the experiment on page 279. Take new measurements of the horizontal distances. Compare them with the measurements taken when the board is flat. Are the distances the same? How would this affect a satellite's orbit?

2. Which will travel faster down a track, a light marble or a heavy marble? To find out, do this experiment on a long, smooth, level floor. Set up a piece of angle iron or aluminum track. Weigh the marbles. Then place them on the track and let them go. Which marble traveled faster? Did you find the answer you expected? Can you explain what you found out? Compare the distances each one traveled. Did the marbles travel the same distance? Why?

3. Look at the chart showing escape speeds from some bodies in the solar system. Can you explain why the escape speeds from these bodies are not the same?

Escape Speed

Planet	Miles per Second
MERCURY	2.5
MARS	3.2
VENUS	6.4
EARTH	7.0
JUPITER	37.5

4. Use an encyclopedia to find out about experiments performed by the following spacecraft groups: *Pioneer, Transit,* and *Telstar.*

5. Suppose you are in a spacecraft moving in orbit at 5 miles a second. You shoot a rocket in the same direction in which you are moving. It speeds away from you at 2 miles a second. Can you explain what will happen to the rocket?

6. Suppose the rocket is shot 2 miles a second in the direction opposite to the motion of the spacecraft. Explain what will happen to the rocket.

Men Venture into Space

One of the greatest adventures of mankind has begun. Man has orbited the earth and returned safely. Now he is able to learn firsthand about space and space travel. Let us find out how he has accomplished this.

The space pilot lies strapped in his spacecraft waiting for the take-off. Everything is ready. Seconds later the powerful engines that have been warming up beneath him thunder to life. The rocket lifts off the launching pad and climbs toward the sky. Another man in another spacecraft is going into orbit.

Who are the men who ride rockets into space? In the United States they are called **astronauts.** Russian space pilots are called **cosmonauts.** You have probably seen their pictures in newspapers and magazines, and on television.

Feeling Weightless

Astronauts feel weightless when they travel in space. You experience something of this peculiar feeling of weightlessness when you swim. When you float in water, you feel almost as if you had no weight. It is a pleasant sensation, but how would you feel if there were *no* water in the pool and you still floated?

To learn more about this strange feeling, astronauts are flown in a special type of airplane. The seats are removed, and the cabins are empty. The

John Glenn was the first United States astronaut to orbit the earth. On the right, astronauts Grissom and Young get ready to make the first United States two-man flight into space. Below on the left is a Russian cosmonaut, the first man to leave a spacecraft during its flight. On the right is United States astronaut Edward White, walking in space attached to his spacecraft by a cable.

walls and floors are covered with soft materials. High in the air, the plane goes into a steep climb. Then it noses down in a curve toward the earth. The plane and its passengers are moving under the same pull of gravity. The plane is not pushing up on its passengers, nor are the passengers pushing down on the plane. They float around the cabin, feeling weightless, for half a minute. Astronauts take many of these flights to get used to the sensation of weightlessness.

On long space flights the spaceship and everything inside will be weightless. Objects such as furniture and equipment will have to be very firmly anchored in place.

The first astronauts to circle the earth managed very well during the short time that they were weightless. What will happen on longer flights? Scientists are doing many tests to find out.

Weightlessness presents problems in eating and drinking, too. How can the astronaut keep from spilling his food? One solution has been found. Astronauts use a squeeze bottle for food. The bottle keeps the food in place. When the bottle is squeezed, food travels through the tube into the mouth. Can one swallow without the force of gravity? How can you find out?

It may be necessary to produce **artificial gravity.** The circular motion of a machine called a **centrifuge** (SEN-truh-fyooj) produces a force similar to the force of gravity. Perhaps the cabins of spaceships will be made to spin. Then a person in the cabin would feel as if he had weight.

Eating in space can be done by using plastic squeeze bottles.

G Forces

Astronauts do not always feel weightless when they fly into space. During lift-off, the rocket continually gains speed. As the rocket climbs, the astronaut is pressed into his seat with great force. His weight may be eight times the normal pull of gravity. This condition is called 8 **G's.** When he re-enters the atmosphere and his capsule slows down, his body tends to move forward with great force.

Lt. Col. Stapp rode a rocket-propelled test sled that in 5 seconds reached a speed of 421 miles per hour. Col. Stapp's body felt a force of 12 G's. The last three pictures show what happened when thrust stopped because the rockets burned out. The force on Col. Stapp was 22 G's. Why are such tests important?

You can get some idea about **G forces** in an automobile. If the car came to a sudden stop, you would be thrown forward. To keep you safe when a car stops suddenly, all cars should have seat belts to hold you in place.

What happens to an astronaut at 8 G's? His arms feel as heavy as lead, and he can hardly lift them. He may find it difficult to speak. His heart pumps faster, and breathing becomes difficult. Every part of his body seems to be eight times its normal weight.

Years ago nobody knew how these G forces would affect people. To find out more about this problem, a special sled powered by rockets was built. It ran on rails. The sled could move from a standstill to 600 miles per hour in a few seconds. It could stop just as quickly.

Models of human beings went on the first test rides. After each test, the models were carefully studied to see how the ride affected them. Later, an Air Force doctor, Colonel John P. Stapp, rode the sled. The sled roared down the rails. For a few seconds he was pressed to his seat with a force 12 times his weight. Normally, Colonel Stapp weighed about 160 pounds. On this ride, how much force was pressing Colonel Stapp backward?

What happened to Colonel Stapp? Although nothing hit him during the ride, he got two black eyes. How did this happen? Colonel Stapp made even faster rides in the rocket sled. From these experiments, it was learned that men are not seriously injured when subjected to **high-G forces** for short periods.

DEMONSTRATION

How Does a Centrifuge Work?

What You Will Need

small rubber ball 3 feet of string

How You Can Find Out

1. Tie one end of the string around the ball. Tie it tightly so it will not come loose.
2. Go out on the playground. Make sure no one is in the way. Hold the end of the string and start twirling the ball. Keep it moving in orbit around you at a steady speed.
3. Now swing the ball more rapidly. This will make it orbit more quickly than before.

Questions to Think About

1. What do you notice about the pull on the string?
2. How does this show you how a centrifuge works?

Each rocket-sled experiment lasted only a few seconds. But astronauts are likely to experience high G's for several minutes. Can a man learn to think clearly and do work under this force? How can scientists find out?

A special machine, the centrifuge, was built to find out. The picture shows you what it looks like. The astronaut rides in the seat at the end of the beam. The beam starts spinning with a circular motion. As the beam spins, a force presses against the astronaut. It acts just like artificial gravity. The faster the centrifuge spins, the greater the force exerted on the astronaut. The activity on page 292 will help you understand why this is so.

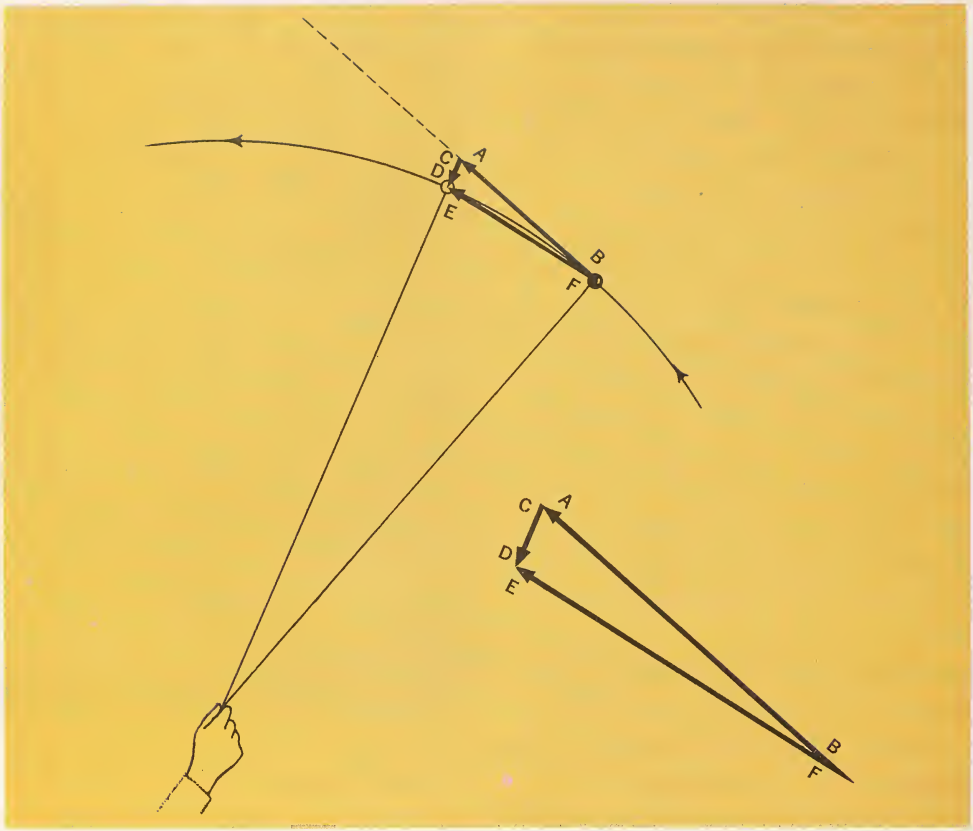
Newton's laws help explain the circular motions of all objects—a centrifuge, a spinning ball, a spacecraft, or the moon.

An astronaut takes a ride in a centrifuge to prepare himself for conditions he may face during his flight into space.

In the experiment, when you first twirled the ball into orbit around you, the string had to be pulled inward just a bit. You quickly found out how much force was needed to keep the ball in its orbit. Remember, the force you exerted was a constant force. Look at page 294.

When you apply a constant force, objects speed up. The constant force of the string makes the orbiting ball speed up. This increase in speed is in the direction of your hand at the center of the circle. The ball tends to move inward, toward the center.

But another force **(AB)** acts on the ball. You gave the ball force when you started it moving at a certain speed. According to Newton's first law, the ball should continue to move in a straight line at that steady speed unless another force acts on it.



Use the diagram to help explain the text below about the swinging ball.

You apply the force **CD** when you pull in on the string. When this force is applied to the ball, it "falls" toward your hand. Why does the ball continue to move in the same path **(EF)** at a steady speed? Look at the diagram. The lengths of the arrows represent the sizes of the forces acting on the ball.

Suppose the forward speed of the ball is increased. To keep the ball in the same path it traveled before, the force pulling the ball toward the center must be increased. Draw a diagram to show this. Compare the sizes of the forces in your diagram with the sizes of the forces shown for the slower motion above.

In these two examples, you learned about the forces when a ball is in circular motion. Do you now understand these forces better?

When astronauts are spinning rapidly in a centrifuge, they are acted on by a force many times the force of gravity. After a while the astronauts learn how to live, work, and solve problems while these forces continue to act upon their bodies.

Longer Space Flights

Man has journeyed into space for only short periods of time. What problems must be solved before man can go farther into space? What solutions are scientists suggesting for these problems? How can you find out?

Outer space has no air. Three hundred miles from the earth there is not enough air to keep a man alive. In fact, almost all of the earth's atmosphere is within the first 23 miles. On a trip far into space there would be air for only a few miles of the flight.

The atmosphere has pressure. It pushes upon your body. The air in your body has pressure. The air in your body pushes outward. These pressures are nearly the same. Because they almost balance each other, you do not feel either of them.

Since there is no atmosphere in space, there is no atmospheric pressure. In space there would be pressure outward from the air in the body but no pressure on the body from outside. This would be fatal. You can see why spacecraft, space stations, and space suits will have to be pressurized. Then people inside them will have almost the same pressure on them that they usually have on earth. Scientists have worked on this problem for some time. The first astronauts wore pressurized suits on their trips, and their spacecraft had pressurized cabins.

All living things need oxygen. On long space flights, travelers will need a plentiful supply. Oxygen could be placed in storage tanks before the rocket takes off. But the tanks are very heavy, and the take-off load would be great.

Another way of getting oxygen might be to pick up supplies at space stations along the way. But how could the space stations get their oxygen supply?

Scientists are experimenting with a way of producing oxygen inside the spacecraft. They are using tiny green plants called **algae** (AL-jee). The algae are placed in large water tanks, where a bright light shines on the algae. As they grow, algae use carbon dioxide and water to produce food. At the same time, they give off oxygen.

EXPERIMENT

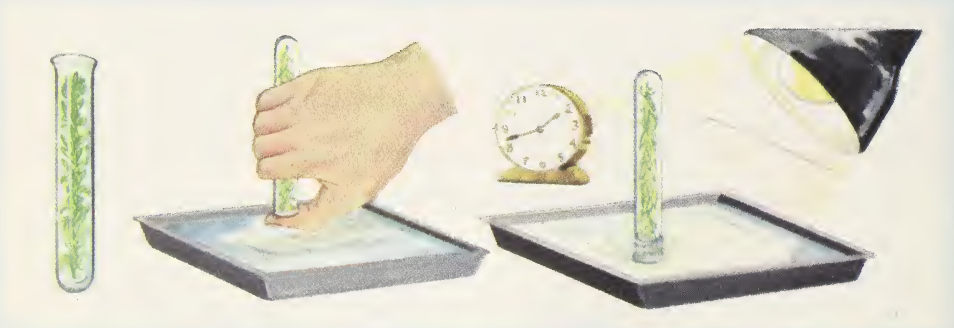
How Can Oxygen Be Made by Using a Plant?

What You Will Need

elodea (from a pond, aquarium, or pet shop)
small test tube
small pan

How You Can Find Out

1. Fill the test tube with water. Put in the elodea plant.
2. Fill the pan with water almost to the top.
3. Cover the top of the test tube with your fingers or a small piece of cardboard.
4. Carefully turn the test tube over so that its mouth points down to the water.
5. Place the test tube with the plant into the water and remove your fingers. The water should remain in the test tube.
6. Make certain there is no air in the test tube.
7. Carefully place the materials under a very bright light and leave them there for thirty minutes.



Questions to Think About

1. Did you find any bubbles at the top of the test tube after the specified time? If not, do not disturb the materials. Leave them in the light for a longer time.
2. What are the bubbles you see?
3. How are these bubbles produced?

Use the diagram to show how algae may be used to supply oxygen for astronauts.

In your experiment, a small amount of oxygen was formed. In laboratories, large tanks of algae have produced enough oxygen to keep small animals alive for a long time. This way of producing oxygen may solve the problem of providing oxygen on long space flights.

Let us suppose that the oxygen problem can be solved. Another problem must be solved at the same time. You exhale carbon dioxide, gas that is harmless in small amounts. But in a spaceship, the carbon dioxide in the air will increase. How will the carbon dioxide be removed from the air?

As they grow, algae need carbon dioxide. Since carbon dioxide is exhaled by the space travelers, the algae can take in the carbon dioxide that would be harmful and, at the same time, give off oxygen needed by the passengers.

Carbon dioxide may also be removed with several chemicals. The carbon dioxide combines with the chemical substance. It is no longer carbon dioxide. It is part of a chemical compound. Spaceships would have to carry large amounts of chemicals to remove carbon dioxide from the air.

Food in Space

For long space flights, a large supply of food will have to be carried. You know that many foods spoil in a short time.

Scientists have found some ways to preserve certain foods. One way is by **irradiation** (ih-ray-dee-AY-shun). The foods are placed in a special container. Strong ultraviolet and X rays are passed through the food. The rays do not seem to harm some food. The rays keep such food fresh for years without refrigeration.

Another way to preserve food is called **freeze-drying.** First the food is frozen. Then it is placed in a machine that removes the frozen water from the food. The dried food lasts for a long time.

Water for Space Travelers

Space has no water. Without a supply of drinking water, human beings would not be able to make long space journeys.

Scientists do not know exactly how much water will be needed. They believe that each person will probably be able to survive with an average of two quarts of drinking water daily. The amount will depend on two factors—the temperature inside the spacecraft and the activities of the traveler. Can you explain why?

One way of solving the problem of water for space voyagers will be to use a small supply of water over and over again. After the water is used, it may be purified in several ways. One way is by evaporation. Try the experiment on page 299 to see how this might be done.

In the experiment, heat from the sun changed some of the water to water vapor. The vapor condensed on the wrapping. The drops of water were not salty. The salt remained in the liquid in the pan.

By evaporation, dissolved substances can be removed from water. In this way, water may be purified in space and used over and over again. How does this compare with the way in which we get fresh water on earth?

Danger from Light

Space is dark. From the earth the sky appears blue because light is reflected from particles in the atmosphere. In space there are no particles to reflect light. The sun is a blazing light, and the other stars shine brightly in the sky. The space around these objects is black.

When a spacecraft enters space, the light may enter a window and be reflected inside the ship. The cabin will be a dazzling contrast to the darkness outside. The contrast will be much greater than we are used to on earth.

The human eye can adjust to light and dark. Observe someone's eyes when the amount of light is suddenly changed. Watch the pupil adjust to light.

A spaceman has to be very cautious about his eyes. When he faces away from the sun, there is almost complete darkness. The pupils of his eyes adjust by opening wide. If he quickly turns his head toward the bright part of the spaceship, it could be dangerous.

How do your eyes feel when you walk from darkness into bright sunlight? Of course, spacemen are carefully trained never to look directly at the sun. Looking at the sun would be painful and harmful. Scientists do not know yet how eyes will be protected in space. This is a problem that must be solved.

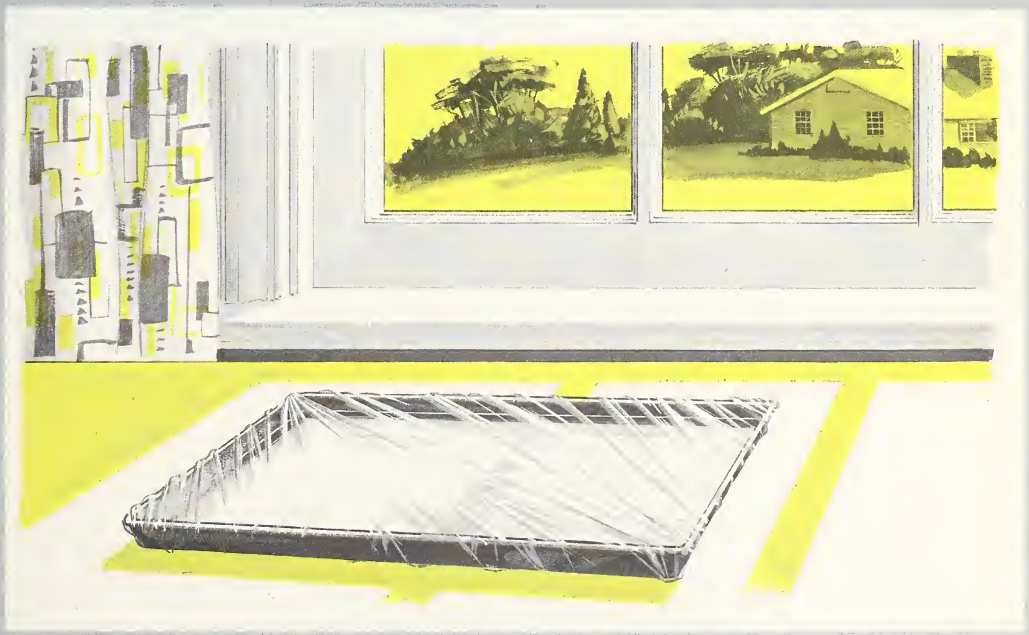
How Can Water Be Purified by Evaporation?

What You Will Need

flat baking pan
1 tablespoon of salt
1 quart of water
transparent food-wrapping paper or plastic bag

How You Can Find Out

1. Dissolve the salt in the water and taste the solution.
2. Pour the solution into the pan.
3. Cover the pan carefully with the transparent paper or a plastic bag.
4. Place it in sunlight for several hours.



Questions to Think About

1. What did you notice on the paper covering the pan?
2. Slowly remove the paper and taste some of the drops. Describe their taste. How do you explain the change?

Danger from Other Radiations

Space contains deadly rays. Our atmosphere protects us from these rays. Out in space two kinds of radiations may be fatal to space travelers. You know about cosmic rays in space. These rays are very strong. They can pass through many inches of lead. No one knows how long a man can survive when exposed to cosmic rays in space. The first astronauts did not orbit high enough to pass through the dense cosmic-ray belts. Scientists are studying astronauts to learn about the effects of low exposure to cosmic rays.

Other dangerous rays come from the sun. These rays are produced by **solar flares.** Satellites helped scientists discover these rays and measure their strength. From time to time these flares send thick streams of atomic particles and dangerous rays far into space. If these particles strike the walls of spacecraft, people inside may be killed. As scientists study the sun, they search for more information about solar flares. If flares can be forecast, space flights will be delayed until the danger is past.

Protection against dangerous radiation in space is a difficult problem. How will it be solved? Scientists will have to find a solution to this problem before men can travel safely in space.

Great streamers of glowing gases, called solar flares, shoot out from the sun.

Danger from the Sun's Energy

Space has no heat. Does this surprise you? After all, the sun shines on the entire solar system. Energy from the sun travels through space. But this energy must be absorbed by something to produce heat. If there is nothing in space to absorb the sun's energy, there is no heat.

On earth, the atmosphere protects us from the intense energy of the sun. In space, there is no natural protection. Some of the sun's energy will be reflected from the spaceship. Some will be absorbed and cause heat inside. The spaceship will have to be constructed

How Do Dark and Light Colors Affect the Absorption of Heat Energy?

What You Will Need

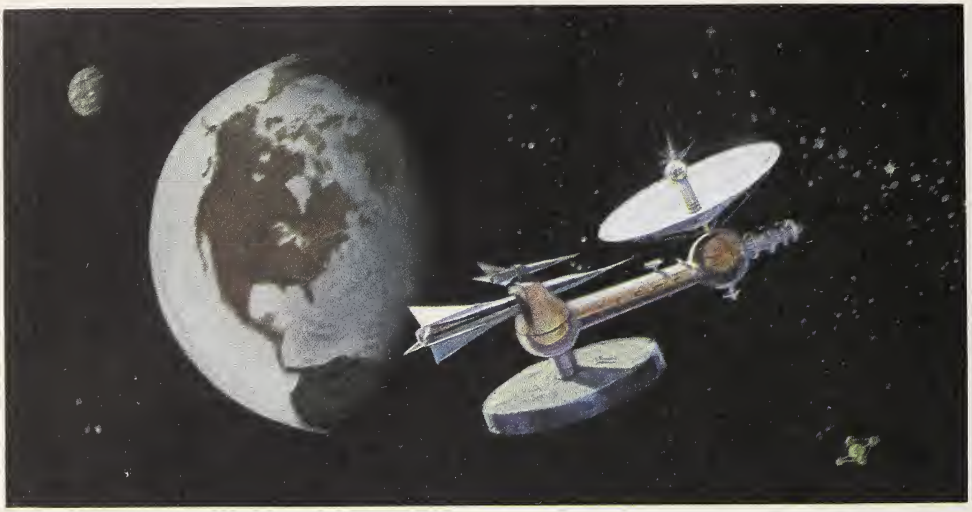
3 metal cans of the same size
3 room thermometers
black and white tempera paint
soil

How You Can Find Out

1. Paint two cans white and one black. Let the paint dry.
2. Paint black stripes from top to bottom all the way around one of the white cans. Now you have white, black, and black-and-white-striped cans.
3. Put one inch of soil in each can.
4. Carefully place a thermometer in each can.
5. Add more soil around each thermometer until the cans are about two-thirds full.
6. Make sure you do not cover all the numbers on the thermometers.
7. Read the temperatures and keep a record of them.
8. Now place the cans in bright sunlight.
9. Use a heat lamp if the sun is not bright enough.
10. Take temperature readings at 5-minute intervals for 30 minutes. Record your readings.

Questions to Think About

1. How did your results compare after the observations were completed?
2. Do dark and light colors differ in the amount of heat energy they absorb?
3. If you found that the cans did not heat at the same rate, tell which one heated the fastest. Which heated more gradually? Can you explain your results?
4. Using striped surfaces may be one way to solve the problem of temperature control in spaceships. Can you tell why?



This is one artist's idea of what a space refueling station might look like.

so that it absorbs just the right amount of energy for comfort. Otherwise it will be impossible for the passengers to remain alive.

How might this be done? From experiments, you have several clues to the solution of this problem. Which reflects energy better, a light object or a dark one? Which absorbs more heat, a shiny object or a dull one? On spaceships, a careful balance of materials may help solve the problem of heat.

One solution that has been suggested is to paint the spaceship with black stripes from front to back. Will this solution have any effect on how much heat energy is absorbed?

Space Stations

Rocket ships will not be able to carry all the fuel they will need for long trips. Space stations will probably be built where rocket ships can refuel. These stations would be constructed somewhere beyond 300 miles above the earth. Can you tell why? They will revolve around the earth in a fixed orbit, just as the moon does.

At a distance of 1,050 miles beyond the earth, such a space station will have to go around the earth at a speed of almost 18,000 miles per hour. At this speed, it will be pulled toward the earth in a curved path so that it will never hit the earth. Instead, it will remain in orbit.

How is this spacecraft being slowed down? Why must it be slowed down?

Space stations might be built in the shape of a ring. If the station spins slowly, people inside the ring will feel the effects of circular motion. The forces will be like those in a centrifuge. In this way, artificial gravity will be produced in the space station.

Because of the absence of gravity as space stations orbit the earth, things in them would be weightless. Rockets leaving the stations for long space flights would not need as much power to leave as they needed to overcome their great weight at the surface of the earth and leave the earth.

Earth-launched rockets must climb through the atmosphere to reach space. They must be streamlined so that the air flows around them. But in space, air friction is no problem. Rockets launched from space can be built in any shape that is best for the long trips.

Returning to Earth

Sooner or later, voyagers will have to return from space and land on the earth. Far out in space, the earth's gravitational force has very little effect on a spacecraft. As the spacecraft nears the earth, however, the gravitational force becomes greater. The ship goes faster and faster. Close to the earth, it may travel as fast as 7 miles a second. Small rockets attached to the spacecraft

will be used to slow it down. It will then be guided into a landing path so that it will enter the atmosphere at an angle rather that shoot directly down toward the earth. Because it enters at an angle, the spaceship will go through the denser parts of the atmosphere gradually. The friction, which will slow down the ship, will also cause it to become very hot. Some way must be found to keep it from burning up as it re-enters the earth's atmosphere.

Scientists are now testing two methods of re-entering the atmosphere from space. The Mercury capsule has a special fiber glass shield on the bottom. As the capsule speeds into the dense air of the atmosphere, the shield becomes red hot. It starts to melt from the friction. But inside the capsule the astronauts do not feel the 3,000° C. temperature. In minutes the friction slows the capsule to a few hundred miles an hour. Then a parachute lands it gently on the water.

The other method of landing is being tested by the X-15 rocket plane. This plane has two skins. The outside skin is a special metal that will not bend or soften from heat. The inner skin and the cabin are kept cool by a special refrigerator. Wings allow the X-15 to glide into the atmosphere very gradually. It loses speed slowly. Air friction during a slow descent is not great. In the lower atmosphere, the rocket plane is controlled and landed like a regular plane.

Interplanetary Travel

Soon man will journey to the moon and return. You know that many problems must be solved before such long voyages in space are undertaken. Then human beings may travel to nearby planets. Scientists believe this may happen in your lifetime.

Space travelers will have to be alone in space for a long time. How will they get along separated from their families and friends? Can man adjust to living in the silence of space? No one knows. But every day, scientists are testing ideas to find the answers.

Attached to the large aircraft is the X-15 rocket plane. Why is it attached in this way?

Using What You Have Learned

1. Make a list of things that you do that depend on gravity. Check each one that you would have to do on a space journey. How would you do these things?

2. Experiment to find out how much oxygen your aquarium plant can make in a week. Use the same equipment that you used for the experiment on page 296. Every day blow some carbon dioxide through a straw into the water. Measure the amount of oxygen collected in the test tube daily. Make a graph showing how much gas was produced.

3. Read and report on the first manned flights into space. A librarian will help you find information in books and magazines. Look for this information: How long did the flight last? How were the men dressed? What experiments did the men have to do in space? What were their experiences with weightlessness? What did they discover about space? How was the capsule made to re-enter the earth's atmosphere?

4. *Nova* and *Saturn* are two launch rockets planned for future space flights. Read and report about them. Look for the following information: What is a *booster?* What job is each booster designed to do? How much thrust will each booster develop? How big a load will each be able to place in space? What fuels are now being considered for use in these rockets? How tall will each launch rocket be?

5. Paths to other planets will not be ellipses. What will the paths be like? Look this up in books about space travel, such as *Orbits* by Hy Ruchlis.

6. Imagine you are an astronomer working on a space station that orbits the earth. What advantages would you have in making your observations of the skies from space?

WHAT YOU KNOW ABOUT

Probing Outer Space

What You Have Learned

Rockets and **satellites** are man's newest means to explore the universe. Great forces are needed to send rockets into space. The force of a rocket engine is called its **thrust.**

To reach the great speeds necessary to place spacecraft in orbit, scientists use **multistage rockets,** made up of two or more rockets.

Spacecraft that explore far into space are called **space probes.** To launch such a probe, powerful engines boost the spacecraft's horizontal speed to about 7 miles a second—the **escape speed** from the earth. At this speed, spacecraft escape from the earth.

Astronauts feel **weightlessness** when they travel in space. During lift-off and re-entry the astronauts experience **G forces.**

Scientists are trying to lessen the effects of weightlessness and G forces in space by studying **artificial gravity** made by **centrifuges.**

In space, astronauts must be protected from **cosmic rays** and the rays from **solar flares.** They also have food problems. Scientists are studying **irradiation** and **freeze-drying** of food.

Because rocket ships will not be able to carry all the fuel that will be needed for very long space trips, space stations will probably be built where the rocket ships can refuel.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

action-reaction	escape speed	rocket	space probe
cosmic rays	G force	solar flares	thrust

Match the Scientists with Their Work

Number a page in your notebook from 1 to 5. Look at the list of names below and match the scientist to his work as given in the list below the scientists' names.

a. Robert Goddard
b. Colonel Stapp
c. Montgolfier brothers
d. Captain H. C. Gray
e. Auguste Piccard

1. Developed hot-air balloons
2. Gave scientists a better idea of temperature in the atmosphere
3. Went 51,000 feet in a closed gondola
4. Developed the liquid-fuel rocket
5. Went over 600 miles per hour to test G forces

Complete the Sentence

Write the numbers 1 to 5 in your notebook. Next to each number, write the answer that best completes each sentence below.

1. The force of a rocket engine is called the ___?___.
2. Spacecraft that explore far into space are called ___?___ ___?___.
3. High-speed atomic particles that come from outer space are called ___?___ ___?___ .
4. Spacecraft that go into orbit are called ___?___.
5. Scientists are trying to produce oxygen inside spacecraft by using tiny green plants called ___?___.

YOU CAN LEARN MORE ABOUT

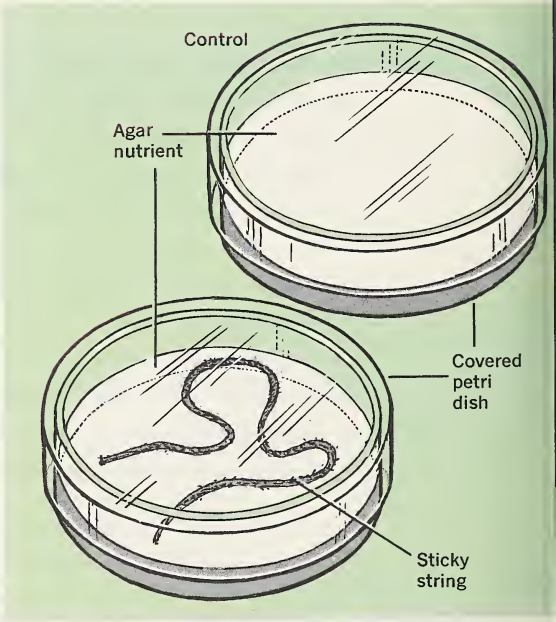
Probing Outer Space

Try This

To find out if there is life on other planets, space probes may use the *Gulliver* or *sticky string* method. After a spacecraft lands on a planet, a sticky string or tape will be unrolled to pick up whatever is on the planet's surface and bring it back to the spacecraft. Inside will be nutrients necessary for the growth of living organisms. If there is life and it can use the nutrients, this information can be radioed back to the earth.

To get an idea of how the sticky string will work, sterilize some petri dishes and pour in agar to ⅛ inch. Cover and let cool. Drag a few 8-inch pieces of damp sterilized string across the floor or lawn. Next, place them in the agar. Use one petri dish as a control—that is, do not place a string in it. Cover each dish and keep in a warm place for a few days. *Do not open them.* Observe the dishes each day and keep a record. Do you see any life?

Do any forms of life grow on the control? Does the experiment show that all living things that are on the nutrient have been detected? From this activity, can you tell what living things need for growth?



Keeping a Spacecraft Log

On a large sheet of paper make 4 columns as you see in the picture. In the last column, under the heading *Purpose,* write how spacecraft put to use our scientific knowledge to make our world a better, safer place in which to live. As you keep your chart up-to-date, think about some problems on the earth that might be solved with greater knowledge about space.

SPACECRAFT LOG

Name of Spacecraft	Date of Launch	Type of Spacecraft	Purpose
Tiros VII	June 19, 1963	Weather satellite	To take pictures of earth's cloud cover. To increase man's ability to predict the weather.

You Can Read

1. *Guide to Rockets, Missiles, and Satellites,* by Homer E. Newell. Descriptions of spacecraft with many photographs.
2. *Robert Goddard: Space Pioneer,* by Anne Perkins Dewey. A biography of the father of the liquid-fuel rocket.
3. *Space in Your Future,* by Leo Schneider. A clear description of our physical world, the universe, and the advances we are making in space.
4. *All About Satellites and Space Ships,* by David Dietz. This book serves as a good summary of man's plans for space exploration.
5. *Experiments in the Principles of Space Travel,* by Franklyn M. Branley. Simple experiments show how the basic physical laws are being applied to space travel.

9

Probing the Oceans

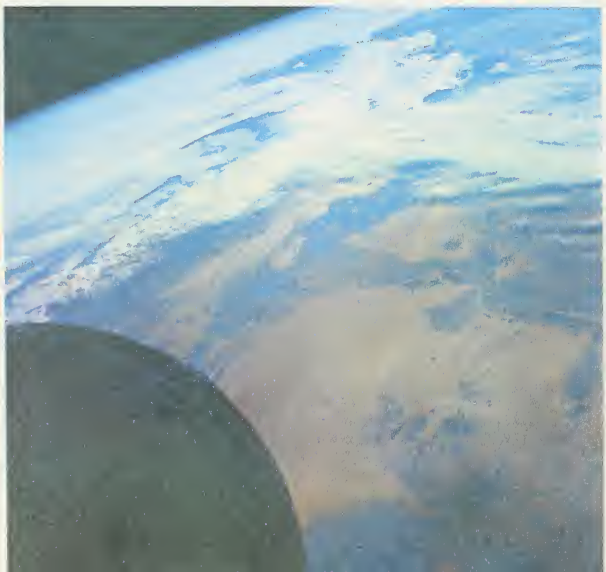
Man Explores Under Water
The Ocean Environment
The Balance of Life in the Oceans

Look at the photograph of the planet earth from 100 miles above it. This is how the earth looks to an astronaut. The dark areas are the oceans. Three fourths of the earth is under water. Great challenges are ahead for underwater explorers, because beneath the oceans lies a little-explored world.

Man Explores Under Water

The study of the oceans and seas is called **oceanography** (oh-shun-OG-ruh-fee). Oceanography is a young science compared with biology, chemistry, or physics. It offers exciting opportunities to boys and girls who are thinking about a career in science. In this unit, you will learn of some of the challenges that lie ahead for those who study the oceans.

Have you ever gone on a long automobile trip or train ride? Did you ever see land for as far as your eyes could see? Perhaps you think the amount of land on our planet is tremendous. An astronaut would not agree with you. When he looks down from high in the sky, he sees water—lots of water. Land is so important in our lives that we for-



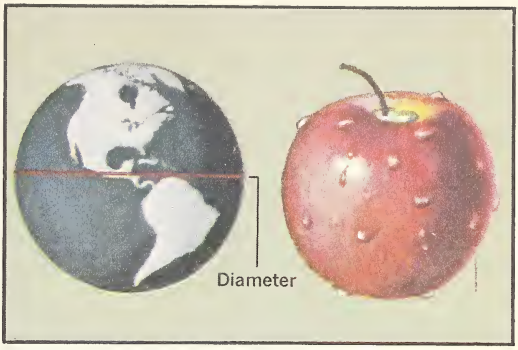
This photograph of our planet was taken from a spacecraft. Can you tell which areas are land masses and which are water? Which areas cover more of our planet?

get that the continents of the earth are islands in a very large body of water. We have used the oceans for food and transportation, but we have always stayed on or near the surface of the water.

To get an idea of how much land there is compared with the oceans, think of this: If the land were scraped off, ground up, and spread over the surface of the earth, the earth would be completely covered by water one to two miles deep.

Now you think that the oceans are tremendous. That is true, but only because you are so small compared with the oceans. If you compare the depth of the oceans with the earth's diameter, which is 8,000 miles, you would find that the oceans are like the thin film of water that clings to an apple after it has been washed.

Why do scientists want to explore the oceans? The most pressing problem on earth is to feed the increasing population, which is using up the supply of natural resources on land. To meet this challenge, man must turn to the sea as a source of food. The oceans may provide great quantities of materials. The oceans may also help man answer questions about how the earth and living things came about: How did life begin in the oceans? How did living things develop to their present stage? How are living things still changing? The oceans may provide some answers to questions about the natural history of the earth.



The depth of the oceans is small compared with the earth's diameter. Think of it as a film of water on an apple that has just been washed.

These are some of the reasons that man studies and explores the oceans. But there is another reason—one which is just as important. Man is curious. Just as man wants to know about outer space, he wants to know about the oceans. For each question scientists answer, a dozen others are raised. The more we find out about our planet, the more we realize how much we do not know! Scientists go on developing theories which lead to answers while, at the same time, nature provides a seemingly never-ending supply of new problems for scientists to solve.

How the Seas Formed

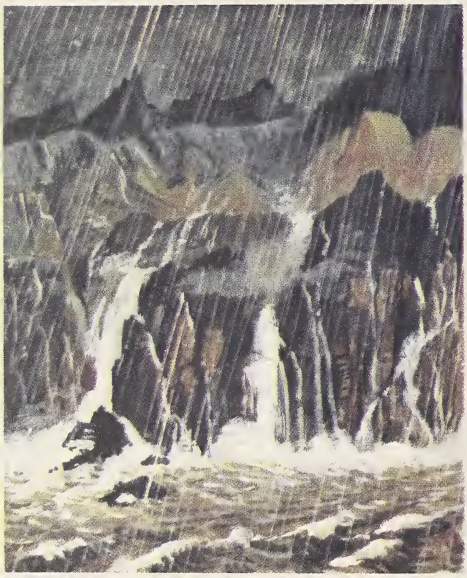
Four and a half billion years ago, the earth was hot, round, and pock-marked. There was no land, no water, no atmosphere as we know it, and, of course, no life.

As the surface of the earth cooled, it slowly shrank. Can you guess what happened to the surface? The surface became wrinkled.

During the millions of years that the surface of the earth was cooling, water vapor in the atmosphere condensed into water and fell as rain. At first, the rain turned to steam as soon as it hit the hot rocks. This went on for a long time, until the earth cooled enough so that the rain did not immediately evaporate. Instead, some of it remained as water and filled the lower areas to form the oceans. If the surface of the earth had been smooth instead of uneven, a blanket of water would have covered the whole earth. That blanket would have been about 8,000 feet deep!

Although we are not certain about how the earth was formed, we are certain that it took a long time.

For many reasons, the surface, or crust, of the earth is still changing slowly. One reason is rainfall. As water runs off the land, it picks up soil and dissolves minerals from the rocks. Some



This picture shows how scientists think the seas may have formed on our planet.

of this water flows into lakes and rivers. Rivers flow into oceans, carrying soil and minerals.

As materials are moved about on the surface of the earth, the earth's crust settles in some places and rises in others. Sometimes changes take place swiftly, as in an earthquake, for example. However, most changes are very, very slow.

Look around you. You may be able to find evidence of some of these changes. Try to find pebbles that have been made smooth by flowing water, or a hillside that has been worn by water.

Exploring the Unknown

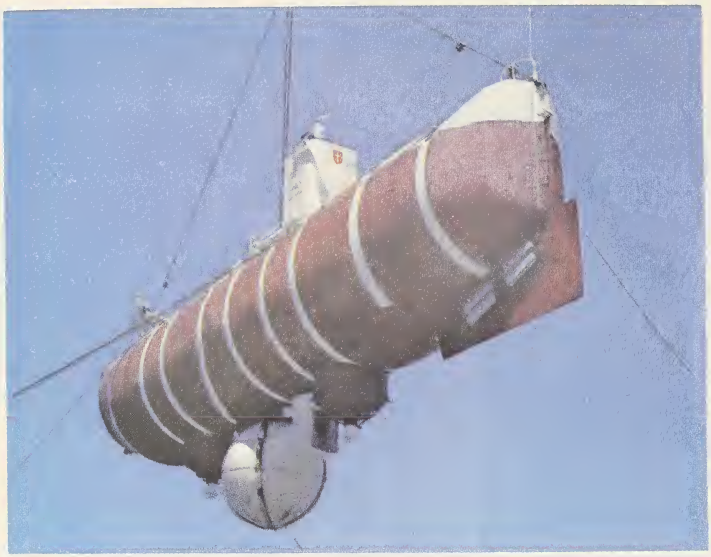
Ocean waters hide the shape of the sea floor. The waters make it difficult to drill into the sea floor. They cover the layers of animal remains that would provide scientists with more information about the history of the earth.

To see through the oceans, scientists must use special instruments and special vessels. They must be able to go down into the water to see for themselves. It is only in the past few years that scientists have been able to explore the ocean floor. Until then, scientists used instruments that collected and measured samples from the surface of the water.

Why has it been so difficult for man to go beneath the surface of the waters? One reason is that man cannot breathe under water without special equipment. The **aqualung** has helped solve that problem by permitting man to dive as low as 40 feet below sea level. This is called skin diving or free diving.

Skin diving has many advantages over helmet diving, in which the diver wears a bulky suit and a heavy metal helmet with windows to see through. Air is pumped through the tubes attached to the helmet. A ship is stationed above the diver to feed him air and to pull him up. In helmet diving there is always the danger that something may happen to

There are many beautiful sights to see and there is much to learn when you know how to skin dive. Skin diving should never be tried without the aid of an expert.



This is the bathyscaphe *Trieste*. The steel ball on the *Trieste's* underside is called the gondola. The steel skin of the gondola is 3½ inches thick and the windows are of clear plastic about 5½ inches thick. Why are the walls and windows so thick?

the air tubes. Skin diving permits the diver to carry his oxygen with him. Another advantage is that the skin diver can swim like a fish and do much more than the helmet diver who is limited mostly to walking.

Skin diving has made it possible for scientists to make maps of the rocks on the floor of the ocean off California. Skin divers have seen landslides under the sea. They have observed and collected specimens of plant and animal life. They have also taken pictures under water.

The skin diver can see and move about at the shallow edges of the sea. The helmet diver or deep-sea diver can go down about 600 feet. But scientists must be able to plunge still deeper. In order to do so, they are faced with a problem. Water exerts pressure on objects that it covers. As you know, air exerts pressure, too, but air at sea level presses with only 15 pounds of force on every inch of the body. In the depths of the oceans, there is so much pressure against a man's body that he would die. He cannot withstand so much force.

The **bathyscaphe** (BATH-ih-skayf) is a deep-sea diving balloon that enables scientists to plunge to a depth of almost seven miles. It was invented by Auguste Piccard who, you remember, is famous as a balloonist.

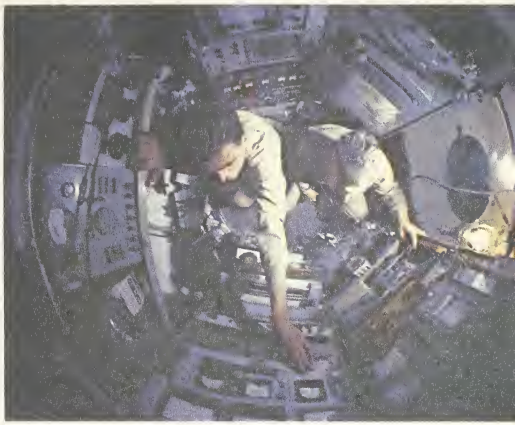
In 1960, the bathyscaphe *Trieste* plunged successfully to 35,800 feet.

This was as great a triumph for science as the placing of a satellite in orbit.

The bathyscaphe works in water just as a gas balloon works in air. Iron shot provides the weight needed to sink the bathyscaphe to the bottom of the ocean. When the scientists wish to return, they simply release the iron shot. They have with them a tank filled with gasoline, which is lighter than water. This enables them to rise to the surface. Observers ride in a steel ball below the gasoline tank. They can control how fast they go up or down. While in the steel ball, the scientists look through windows, called ports. They take photographs and collect samples.

In 1964, Operation Deepscan took French and United States scientists more than four miles below the surface of the sea to study the deepest spot in the Atlantic Ocean, the Puerto Rico Trench. Their bathyscaphe, named *Archimède,* was 70 feet long by 26 feet high. It was built to dive seven miles. The vessel contained a submarine laboratory. It had equipment to measure the pressure, temperature, and speed of sound in water, and to collect samples of water, rock, marine life, bottom mud, and ooze.

When scientists descend to such depths, they have to be protected from the tremendous outside pressures of the water. The bathyscaphe has a strong, watertight cabin that keeps the pressure of the air at 15 pounds per square inch, just as it is at sea level.



Observers get into the gondola by means of a tube 25 inches in diameter. In the gondola are many kinds of cameras, including television cameras, and many kinds of measuring instruments.

How do certain animals live with the weight of the sea against them? To live under such pressure, an animal must be adapted to it. The animal must have the kind of body structure that can stand the pressure. Animals that live in the great pressure of these depths would die if they were brought to the surface by ships. The change in pressure would kill them. They have to be protected against such changes in pressure. The bathyscaphe can keep them at their regular pressure and so bring them to the surface alive.

Man has seen the bottom only of the shallow parts of most of the ocean. However, scientists know much about the deeper parts. They have learned about these areas by using sound waves.

You know that when sound vibrations hit a wall, they are reflected as an echo. You can find out how far away a certain tall building or cliff is with a stop watch. Just shout a word and see how long it takes the echo to come back to you. Knowing that sound vibrations travel at about 1,100 feet a second, you can figure out the distance.

Scientists can find the depth of water by using the same method. Sound vibrations travel faster in water than in air. In water they travel about 4,800 feet a second. When vibrations are made at the surface of the water, the ocean bottom bounces or reflects them. Scientists can tell how deep the ocean is by measuring how long it takes sound waves to reach bottom and return to the surface.

The Bottom of the Ocean

The ocean bottom is divided into three parts. The **continental shelves** are the parts nearest the continents. It is believed that continental shelves were once above the water. They are the shallowest parts of the ocean. Sunlight can get through the water to almost all parts of

PATHFINDERS IN SCIENCE

Matthew Fontaine Maury

(1806–1873) United States

There is a saying, carved into a monument, that reads:

Matthew Fontaine Maury
Pathfinder of the Sea
The genius who first snatched
From ocean and atmosphere
The secrets of the Sea.

As a boy, Matthew Maury listened to his brother's adventures in the Navy. The games he played and the dreams he dreamed were of the sea. His favorite subject in school was geography, because it allowed his imagination to roam the world.

Knowing that he could not attend expensive schools, Matthew decided to join the Navy. In June 1831, Matthew was appointed a sailing master. As his ship sailed across the Pacific Ocean to the Orient, he wondered: Could sailing time be shortened if the winds and currents were used to aid the ship? He felt that the winds and currents must follow a pattern. Wherever the ship docked, Maury filled notebooks with his observations.

Lt. Maury was put in charge of the Depot of Charts and Instruments. He ordered all ships to gather information daily on lati-

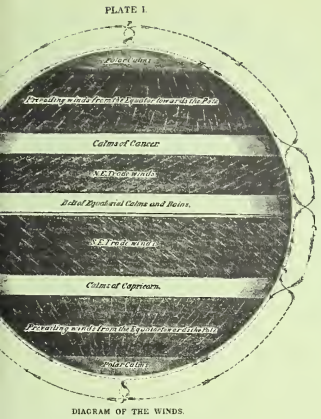
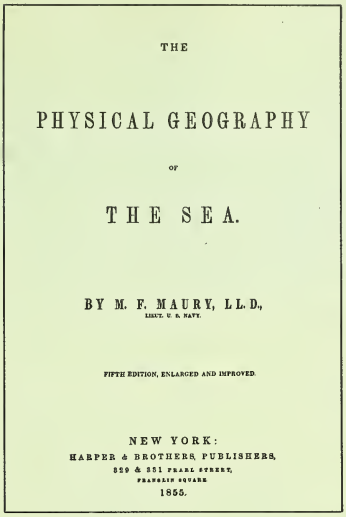


DIAGRAM OF THE WINDS.


THE

PHYSICAL GEOGRAPHY

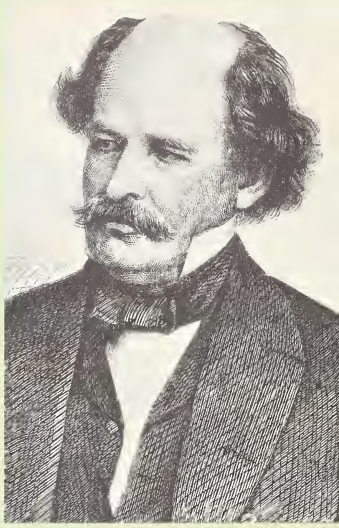
OF

THE SEA.

BY M. F. MAURY, LL.D.,
LIEUT. U. S. NAVY.

FIFTH EDITION, ENLARGED AND IMPROVED.

NEW YORK:
HARPER & BROTHERS, PUBLISHERS,
329 & 331 PEARL STREET,
FRANKLIN SQUARE.
1855.



tude and longitude, hourly rate of currents, speed and direction of winds, temperatures, fogs, the sighting of whales and birds, and barometric pressure before, during, and after storms. He asked sea captains to throw into the water tightly corked bottles containing instructions for their return to the ships' headquarters. The purpose was to estimate the course and speed of the current that carried the bottles. As a result, routes were shortened and sailing times were cut.

Lt. Maury charted the currents of the oceans and proved that they are stable, have direction, and affect climate. He taught sailors how to navigate *with* the seas rather than against them.

In 1855, *The Physical Geography of the Sea* was published. It was written by a man afire with enthusiasm for oceanographic research. The book was used throughout the world. It gave proof of Lt. Maury's hard work, his keen observations, his insight into the many phases of the sea, and his ability to enlist the cooperation of so many.

The highest honor given to Lt. Maury was that the first great oceanographic expedition ship, the *Challenger,* was guided around the world by his charts. Today all charts issued by the United States Hydrographic Office say: "Founded upon the researches made by Matthew Fontaine Maury, while serving as a Lieutenant in the U. S. Navy."

THE BOTTOM OF THE OCEAN

the shelves. Plant life grows well in the water above the shelves. This is where most fish live. Can you see why?

The shelves drop suddenly into steeper hills, called **slopes.** At the bottom of the slopes, there are canyons and valleys.

The **floors** are the deepest parts of the ocean. They are so far down that man knows very little about them. They are a world of complete darkness. Do you think plants grow there?

For a long time man thought that no animals lived in this world of darkness. How could they live without plants, without light, and under such great pressure? Today, we know from research-vessel dives, from echo-soundings, and from specimens that have been pulled out of the depths that there are animals living there.

The depth of the ocean is measured in **fathoms.** A fathom is 6 feet. One of the deepest parts of the ocean is a long trench near the Philippine Islands about 5,700 fathoms deep. The highest mountain on land is about 29,000 feet.

ABOUT "PROBING THE OCEANS"

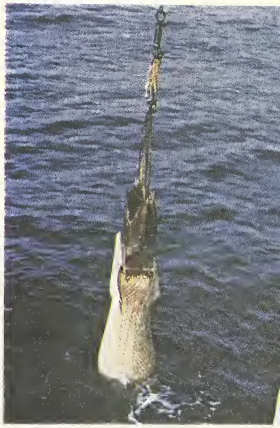
In 1961, President John F. Kennedy said, "Knowledge of the ocean is more than a matter of curiosity. Our very survival may hinge on it." Yet, until the last few years, the study of the ocean has been a neglected science. Although there is now a great deal of research going on in oceanography, more needs to be done. There are many opportunities for those interested in the world's oceans. The next eight pages show you some of the work of oceanographers.

Probing the Oceans

Most scientists interested in marine science work for oceanographic laboratories such as the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts. These seashore laboratories, together with their research ships, carry on investigations in all areas of oceanography. The geophysical oceanographer studies tides, waves, oceanic circulation, and physical properties of ocean basins and of sea water. The marine biologist studies living things found in the sea.

Let's go aboard the research ship **Chain.** A day aboard the **Chain** begins early and ends late. Even while a few sleep, work goes on. The researcher's day never ends.

The large net being lowered is used to collect plankton samples.

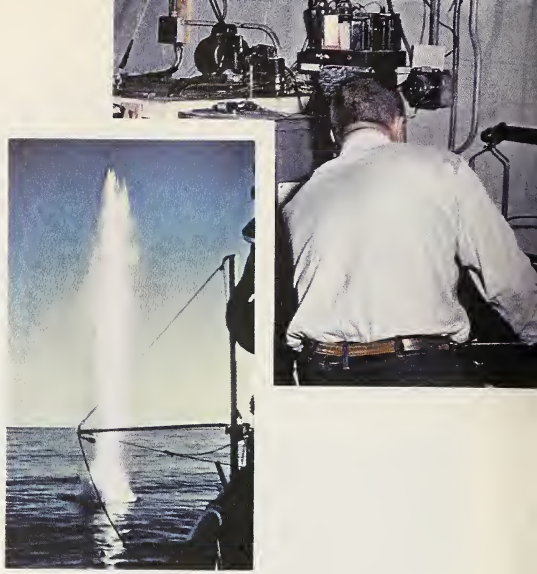


It is late at night as another plankton net is hoisted from the ocean.

Plant and animal life are caught in the net of this bottom surface sampler.

Over the side goes a Nansen bottle to get samples of ocean water. A thermometer fastened to the outside of the metal bottle records the temperature of the water at various depths.

An explosive charge sets off earthquake-type waves that are picked up on sensitive instruments aboard ship. The measurements made from these artificial earthquakes will indicate how thick the layer of sediment on the ocean floor is.



From 900 feet in the ocean comes a bathythermograph, or B.T. This instrument scratches a temperature-depth record on a chemically treated glass plate. The plate is then placed in a viewer so that scientists can read it. This is one of the most useful and familiar of oceanic instruments.

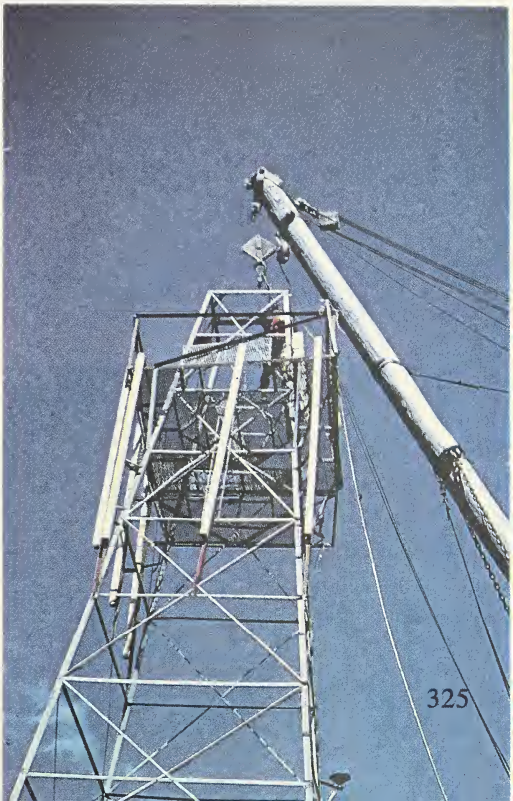
The current meter being raised on to the ship gives scientists measurements of ocean currents at various depths. Measurements of both speed and direction can be made.

Wind speed and direction are recorded by instruments mounted on buoys. This is a transmitting buoy being set into position.

Below decks, a scientist studies a squid, which he will take back to his laboratory on shore.

This is a box corer. It is used to obtain undisturbed samples of sediment.

Stand clear! Wave tower going up.



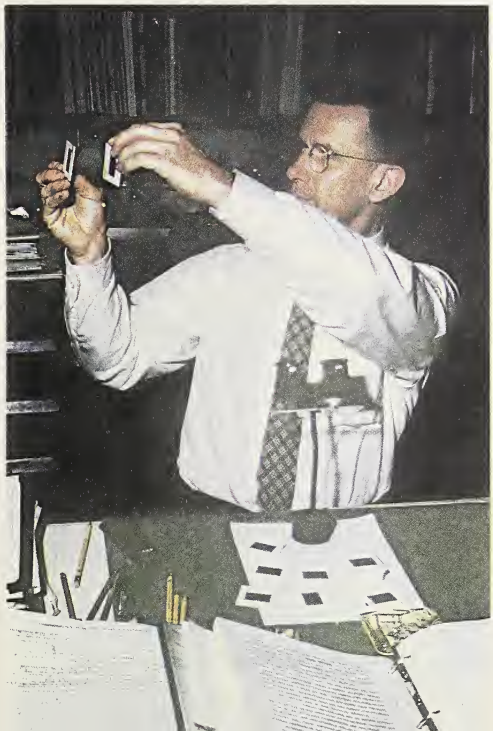
Look what the net brought up — a man-of-war! This jellyfish has tentacles which are able to sting and entangle any small animals they touch.

Here's the finished tower. Two scientists are seen making adjustments. Data about waves are radioed from this tower back to shore.

Man is curious. He needs to see for himself the ocean's ways and life. The cubmarine is a one-man submarine that enables him to explore the deep.

Every ship doing research at sea is backed by a land laboratory. At the laboratory of the Woods Hole Oceanographic Institution, a scientist runs a series of tests on samples collected at sea.

Another scientist uses a salinometer to find how much salt there is in each sample of ocean water.



Another scientist studies pictures taken of the ocean's bottom so that he can write a report of his findings.

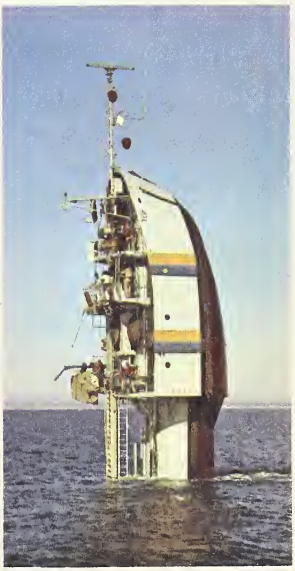
Getting ready for the next voyage means placing letters in drift bottles. Each note asks that the finder mail back the note. The bottles will be thrown into the ocean. Scientists can trace oceanic currents by learning where these bottles are found.

Even airplanes are used by oceanographers. Cameras mounted on airplanes take pictures of changes along a shoreline caused by storms and other forces. Movies record the development of clouds. Special thermometers measure the surface temperature of the ocean and also locate oceanic currents.

Ships, instruments, and computers need people to man, invent, and operate them. Oceanography presents young men and women with an exciting opportunity to explore the last unknown frontier on earth — the oceans.

Using What You Have Learned

1. Besides the vessels described in this chapter, there are others that have been built for exploring beneath the sea. Prepare a report on the small two-man subs that are now being used. Find out about *Flip,* the research vessel that can stand on end.



2. Make a model of the ocean showing the different kinds of living things at different depths. Cutouts of various kinds could be hung by threads at the proper depths.

3. The earth is slowly warming up. As it warms up, some of the snow and ice in the polar regions melts. Tell about some of the effects on ocean and land areas caused by melting.

The Ocean Environment

Life exists in great abundance and in great variety in the oceans. The key to important ideas about these living things is the environment in which they live. We must study their environment to explain how the variety of ocean life developed and how it continues to change.

You might think that the ocean environment is the same all over. Or you might expect the ocean to be warmer in the south and colder in the north, or clear in some places and murky in others.

If you have been to the seashore, you know that even these simple statements are not quite true. Cape Cod, Massachusetts, is in the northeastern part of the United States. Some waters on the Cape are warm enough for summer bathing, while others, only 50 miles away, are much too cold. Even in the same bathing area you can find places that are warmer than others. Water temperature is *not* uniform even in a small part of the ocean.

Have you ever gone swimming in water that was very easy to float on? The sea is salty, but it is saltier in some parts than in others. In *very* salty water, as in the Great Salt Lake in Utah, it is impossible to sink.

Have you seen signs of how life changes in the sea? A few years ago, blue sharks were seen off the coast of New Jersey. This shark usually makes its home in warm, tropical waters. The waters near New Jersey are cold. These sharks seemed to have traveled northward. Every now and then fish move to a different area of the ocean. Part of the reason is that their old environment has changed. Since they cannot survive there, they must move. These observations give us clues to some key ideas of oceanography:

1. The ocean environment is not uniform; it is really many different kinds of environments.
2. The ocean environment is constantly changing.
3. Ocean life is sensitive to even slight changes in environment.

The Changing Oceans

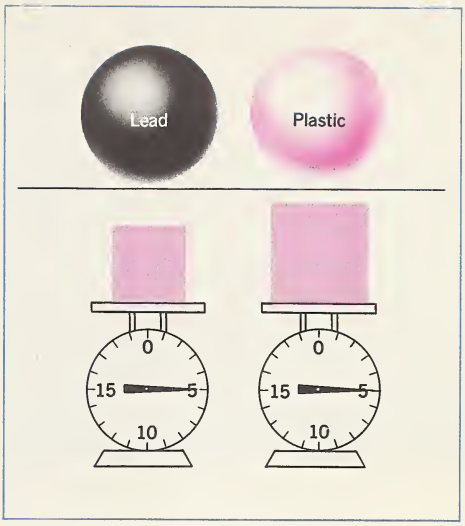
You know that the land is continuously changing. Wind and water cause it to change. Oceans, too, are continuously changing. Scientists study these changes to find out more about the oceans.

Traveling in oceanographic ships, scientists take samples of the water. Sci-

entists record the depths at which the samples are taken. They collect specimens of living things and of the sounds they make. They drop current detectors overboard. These are plastic discs on long, slender tubes that ride along the underwater currents. Each has information on it about where it was dropped. Somewhere, sometime, many of these are found. The finder writes down where he picked up the detector and sends it to the oceanographic institute. Information can be pieced together in this way about how currents are running.

In laboratories on the ships, scientists analyze the samples they have taken. First, they want to know about the watery environment in which an animal lives. How would you go about describing a sample of water?

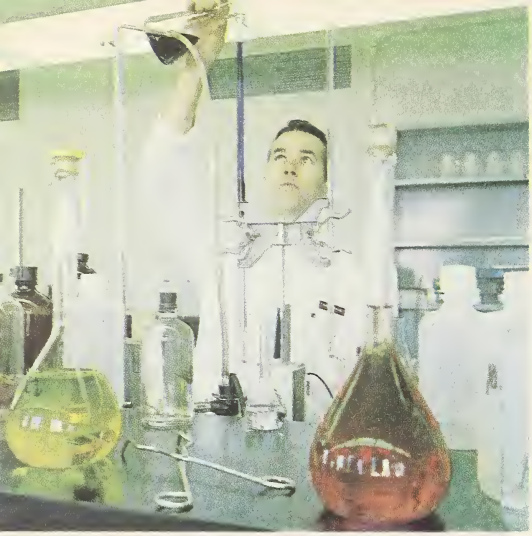
One way scientists can describe water is to tell what its **density** is. What does density mean? Scientists often define something by telling how two things are related. The two things related here are the mass of an object and the space that it takes up. Density is the relation between these two things. A heavy object that does not take up much space is denser than a light object that takes up the same space. A lead ball is denser than a plastic one of the same volume. If two objects weigh the same



Which is denser, the lead ball or the plastic ball? Which is denser, the large box or the small box? How can you tell?

but one takes up less space, then that one is denser than the other. Which is denser, a pound of lead or a pound of plastic?

The density of sea water is not the same all over. Density varies with the elements that are dissolved in the water. Two of these elements, sodium and chlorine, make up our table salt. Other chemical elements that are abundant in the sea are potassium, magnesium, bromine, and calcium. In fact, the same elements that are found on land are also found in the sea. Even silver and gold are found in the sea.



A scientist tests the salinity of ocean water.

Density of water varies with the kinds of elements dissolved in it, as well as with the amount packed into the same space. Why would the *kinds* of elements

Most of the elements in the sea are found as chemical compounds known as salts. Potassium and chlorine combine to make potassium chloride. What elements combine to make NaCl?

Density, then, depends mostly upon the salts dissolved in the water. Scientists are interested in the saltiness of the water. The saltiness of water is called its **salinity** (suh-LIN-uh-tee). Salinity is measured by instruments like the one above.

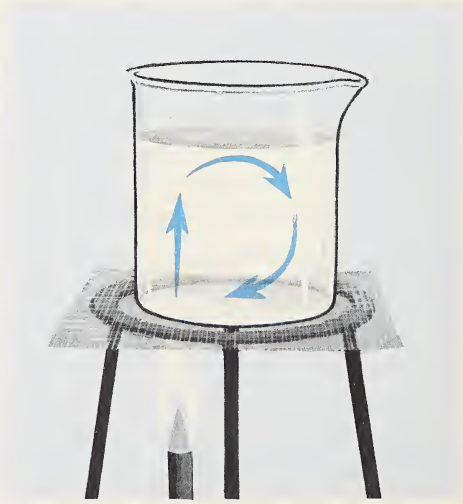
Where would you expect to find the salinity of ocean water the greatest? Samples of water have been taken from different depths. The salinity of the samples has been determined. Scientists have found waters of high salinity at various depths of the ocean.

Ocean Currents

Water in the oceans is constantly in motion. Scientists have found that much ocean water moves in strong ocean streams called currents.

To explain these streams of water in the ocean, we must find out what causes water to move. The process causing movement is **convection** (kun-VEK-shun). Heated matter is pushed by

Explain what is happening in the water in the diagram below.



colder matter. When you put a pan of water over a fire, the water at the bottom of the pan heats up first. As the molecules in the water become heated, they move about faster and also move farther apart. This water becomes less dense. Colder, heavier water is pulled down by gravity and crowds out the warmer water. There is a constant downward and upward movement of water until all of it is boiling.

Now let us see what happens in the ocean. The sun warms the ocean, but it does so unevenly: Tropical waters receive a great deal of heat from the direct rays of the sun. Shallow waters heat up more quickly than deep waters. The sun shines on some parts of the ocean, whereas clouds prevent the sun from shining on other parts. Winds carrying warm air heat some parts, while others are chilled by cold winds.

As waters become heated and less dense, they are crowded out by cooler, denser waters, pulled down by the force of gravity. In this exchange, a current is created. Winds pick up the current and push it along. Large currents like the Gulf Stream are pushed along by westerly winds.

Can you trace the paths of the currents shown in the drawing below?

Ocean Currents and Salinity

Waters in the ocean, then, are not still. They do not rest in layers with the saltiest at the bottom. Ocean currents carry the dissolved salts along with them.

Scientists have made the following observations about the saltiness of ocean waters:

1. Waters near mouths of rivers tend to be high in salt content.
2. Tropical waters tend to be high in salt content.
3. Waters near the North and South Poles are saltier in winter than in summer.
4. The kinds of salts in the water are not the same in all parts of the sea.

Scientists have found these facts about salinity by analyzing samples of water. But how do they explain these facts? Let us start by finding out where the minerals in the waters come from.

As rain water flows over the land, it picks up salt and other minerals. Water, with these salts and minerals, flows into rivers and finally into the ocean. Water is always evaporating from the ocean, but the minerals do not evaporate; they remain in the sea. The amount of minerals in the ocean keeps increasing. Some scientists have tried to tell how old the earth is by the amount of salt or minerals in the ocean. Can you explain how they might do this?

Minerals are added to the ocean in another way. When a weak part of the earth's crust breaks down, some hot liquids and gases from deep inside the earth escape from a volcano. When volcanoes erupt under the sea, minerals from inside the earth are released into the water. When volcanoes erupt on land, there will be minerals on the surface to be washed into the sea.

In tropical regions, water evaporates very quickly, leaving more salts in the remaining waters. In polar regions, the surface waters freeze in winter. As they freeze, the salts drop to the waters beneath. In the winter, then, polar waters are saltier than they are in summer. In the summer, the ice melts, freeing water that is low in salinity. This water mixes with waters high in salts. The waters become less salty.

A Changing Environment and Changing Life

We have seen how the ocean provides many different environments for living things. There are differences in temperature, density, chemical makeup, and movement of the waters.

Ocean life responds to change, but there is a limit to the changes to which a living thing can adjust. A plant or animal can only stand a certain range of temperature. If a polar bear is put into tropical waters, it will die. Tropical fish cannot stand the Arctic waters.

The chemical makeup of water must also be of a certain kind for a plant or animal. You probably know that goldfish will die if you put them in water right out of the faucet. Most of our drinking water has too much chlorine in it for goldfish.

One year scientists noted a sharp drop in the mineral phosphate in the water of the English Channel. Shortly after this, they noticed there was much less plant life in the water and fewer young fish. In a while, there were no more her-

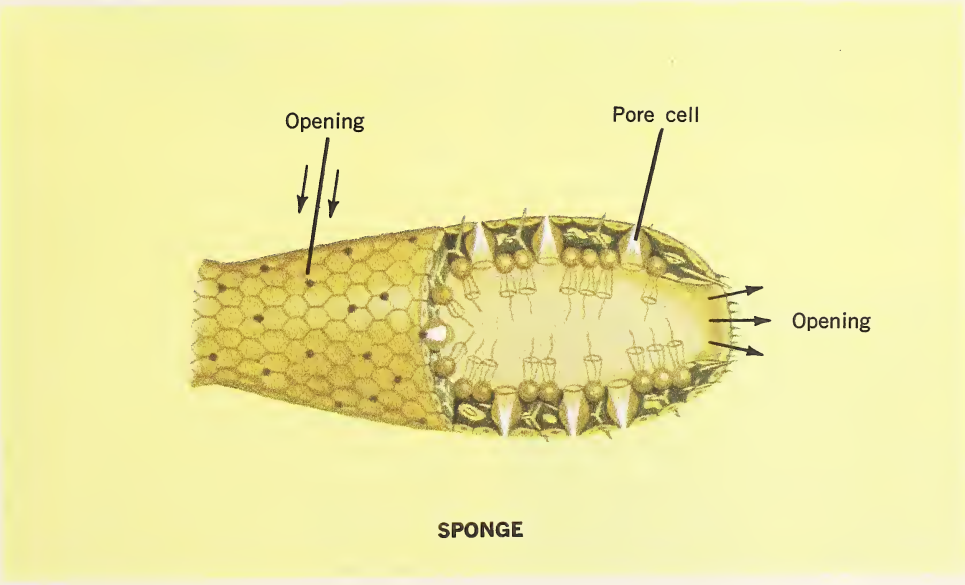
ring. Herring had previously been plentiful enough so that a whole fishing industry depended on them. A change in that section of the ocean environment brought a drastic change in the life found there.

Menhaden, a member of the herring family, are important for the oil they contain. Sometimes as much as 60 gallons of oil is obtained from a ton of fish. At other times, considerably less oil is obtained from the same amount of menhaden caught in the same area. From what you have learned, can you give a possible reason for this difference in oil content?

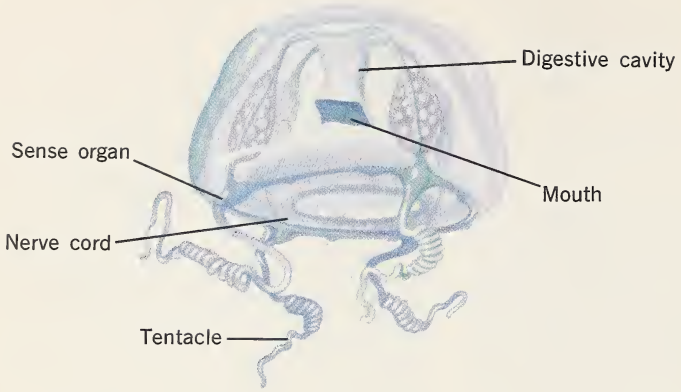
Past Life in the Oceans

In the oceans today, as on the land, we can find very simple and very complex forms of life. Can you think of some simple forms of ocean life you have already studied? Name some land animals that resemble these forms of ocean life.

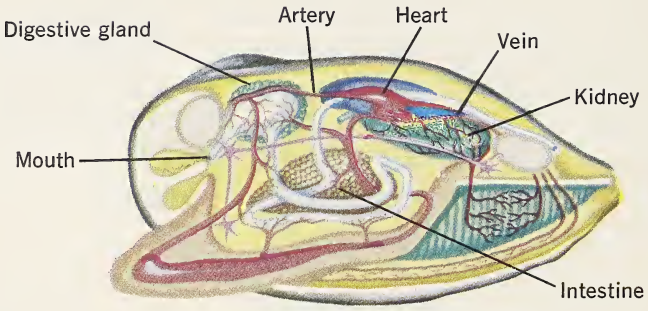
Study the pictures below and on page 336. Here you find the body plans of various animals that live in the sea. You can find examples of how specialized equipment developed. How does the sponge take in food? What equipment does the jellyfish have for food-getting and protection? Study the body plan of the clam. What systems can you identify?



SPONGE



JELLYFISH



CLAM

About one hundred years ago, some scientists tried to learn more about the origins of life. They thought that the first animals lived in the sea. Might some of these kinds of animals still exist at the bottom of the sea? Living things have changed over millions of years, but perhaps in the depths of the ocean there might still be found the same animals.

In the depths, conditions have remained much the same for millions of years. No sunlight has ever shone through. In the depths, the temperature is the same at the poles as at the equator. The seasons are the same the year around. There are no winds, no waves, and no currents. The scientists reasoned that in such an unchanging environment, life would not change. They thought that if life had begun in the lowest depths of the sea, then some ancient forms would still exist there.

In 1872, the British launched the *Challenger,* a ship equipped with laboratories and scientists. She traveled the oceans for four years, and her staff made thousands of observations. They fished strange fossils out of the sea. The fossils had living relatives familiar to the scientists. The scientists searched for **trilobites** (TRY-luh-byts). We know such creatures once existed, for there are fossil remains, but no trilobites were found. Scientists analyzed the slimy ooze at the bottom of the deep, but they did not find any living fossils.

Today, scientists believe that life did not begin in the lowest depths of the sea. There are squid and fish living there today, but these creatures have gone down to the lower depths from higher levels. While they are like their relatives living above, their body structures have changed in some ways. The changes have made survival possible in the depths. The squid and some fish have ways of lighting up the dark. The fish are small, but have huge mouths: they do not have large bodies to feed but have a lot of mouth to catch food with. Some fish are blind but have very long feelers so that they can find their way. These specialized parts enable animals to adapt to life in the depths of the oceans.

Trilobites lived about 500 million years ago. They disappeared about 200 million years ago.

How are squids adapted to their environment? How do they protect themselves?

How do blind fish find their way? Where are they usually found?

More life exists at the surface of the sea than in the depths. And it is probable that life began in the surface waters. New forms of life developed; some old ones disappeared. Animals went ashore, but they carried part of the ocean with them. Reptiles, birds, and mammals have in their blood the same elements found in the oceans. Their blood contains the salty elements—sodium, potassium, calcium—in almost the same proportion that these elements are found in ocean water.

Life probably began in the ocean, but man does not yet understand all the ocean's secrets.

Using What You Have Learned

1. If you live near the ocean, you can evaporate a pint of sea water to see how much salt and other minerals it contains. You will find that there is about one tablespoon of salt and other minerals in a pint of sea water. This means there are about 3½ pounds of minerals in 100 pounds of sea water.

2. How can we get back some mineral wealth from the ocean? One way to collect the minerals is by evaporation.

Pour a cupful of water into a shallow pan. Add three tablespoons of salt. Let it stand for several days. Observe what happens. This same general method of evaporating water is used to collect minerals from the ocean.

3. Evaporation was used to get salt long ago in Greece and Egypt. It is still used today in Iran and California. Prepare a special report on how ancient and modern methods differ.

4. Chemical change is another way of collecting some minerals from the ocean. Get some limewater and blow into it. The carbon dioxide from your breath combines with some of the lime and forms a chemical compound. This compound will not dissolve in water. If the water is left standing, the compound will settle in the same way that starch settles in water.

The Balance of Life in the Oceans

The swordfish eats the mackerel, which eats the herring, which eats tiny water animals. What do the tiny water animals eat? They eat plants that float on the surface of the sea. These plants are so small that there are thousands of them in one teaspoonful. Without these tiny plants, nothing could live in the ocean. Big sea animals depend upon smaller sea animals for food. These smaller sea animals depend upon still smaller ones, and the smallest of all depend upon plants. As you can see, no one living animal can exist by itself.

Trace the cycle of life. How is a balance of life maintained?

Plankton

The tiny green plants of the ocean and certain small animals that feed on them are called **plankton** (PLANK-tun). Plankton plants are the basic food of the sea. Each plant is so small that it can be seen only with a microscope.

Plankton is from an ancient Greek word meaning "wandering." Plankton wanders, or drifts, with the currents.

Most plankton plants are **diatoms** (DY-uh-tumz). A diatom is a one-celled green plant. Under a microscope, the diatom cell looks like a little glass

These are diatoms as seen under a microscope. Do you see any chlorophyll within the cells?

box made of two parts. The two parts fit neatly into one another. The living part of the cell, which contains chlorophyll, is in between the two parts. There is a tiny slit in the glasslike box. Through this slit sea water enters the living part of the cell. Sea water contains the carbon dioxide and mineral nutrients that the cell needs to make food. It also contains the oxygen that all living things need. Thus, these plants get materials that they need directly from the water in which they float.

Plankton plants grow best where the ocean water contains the minerals they need. These plants grow best in cool waters. They can grow only as far down as light can reach—about 400 feet. Can you explain why? Warm tropical waters do not contain much plankton. That is why these waters are so clear and blue. It is plankton that clouds the northern waters and makes them look so dark.

Diatoms reproduce in a simple way. Each diatom divides to form two cells. All one-celled plants and animals reproduce in this way.

Diatoms can reproduce very rapidly. Under favorable conditions diatoms may divide as often as eight times in twenty-four hours. At this rate, you could begin with one diatom and have 256 the next day if they all lived.

What happens to plant plankton affects the whole ocean. Without plankton no life could exist in the sea. There are sea animals that eat other sea animals that eat other sea animals. But always at the beginning of the food chain there is the green plant, the diatom of the sea. Even the microscopic animal plankton must get their food from these tiny, one-celled green plants.

Food from the Sea

Plankton can be made into food for people. Plankton can be pressed together and dried. The result is a paste that is very high in food value. It is 50 per cent protein and contains every nu-

trient that man needs. However, people who have eaten plankton do not like it. Furthermore, harvesting plankton requires a great deal of time.

Man can obtain fish more easily than he can obtain plankton. For example, a group of fishermen caught over 58 tons of herring in 100 hours. To collect that much plankton, man would have to strain almost 58 *million* tons of sea water. Some scientists believe we should let fish use the plankton for food. Then we can use the fish for food. But other scientists, especially in Japan and Thailand, are working on using plankton as a direct source of food. Scientists believe that plankton may be used for food on space stations.

Plankton plants grow not only in the ocean but also in fresh-water lakes. They can be grown in tanks, too. All you need to grow them is some of the plants, sunlight, water, and minerals.

These plants may also be used for fuel. When dried, they burn with a slow, hot flame—like coal. It was from living things like these that petroleum was formed millions of years ago.

Seaweed

Seaweed are rather large plants that grow in the sea. They are closely related to some of the plankton plants. They are called algae. The seaweed algae are many-celled plants. Some of them grow to be very large. They are quite different from large land plants. Land plants need roots and stems to get water and minerals. Seaweed plants live in water and absorb minerals along with water through all their parts. Food can be made by all parts.

Most seaweed plants live at a depth of about 10 to 20 feet. They are supported by the water, so they do not need strong stems. When seaweed plants are out of the water, they sprawl all over the ground. Can you tell why?

Seaweed do not have roots; they have **holdfasts.** Holdfasts fasten to rocks or shells on the bottom of the sea.

The photomicrograph shows mixed plankton containing plants and various kinds of small animals. Find out what the animals are.

Seaweed vary in color. Those that grow near the surface of the water are green. Farther down, seaweed are brown and red. These seaweed have chlorophyll too, but their green color is hidden by the brown and red coloring. Because of their coloring, they only need the small amount of light that reaches farther down into the water.

Seaweed is used in many ways. If you have ever felt seaweed just as it comes out of the water, you know it is slippery. This is due to a gelatin-like substance called agar. In the laboratory, bacteria are grown on agar. Agar is also used in making jelly, mayonnaise, and ice cream.

Seaweed is also rich in iodine. How does man use iodine? Meal can be made from dried seaweed and fed to animals.

Some scientists suggest that seaweed could be a fine source of vitamins and minerals for people in areas of the world where food is scarce. There are 836 tons of water in 1,000 tons of seaweed. What problems does this present in using seaweed as food?

If you want to be a scientist who does research on seaweed, there is much opportunity. For example, there is still work to do in identifying the different kinds of seaweed. Does a newly found specimen belong to a new species or to one that has been identified? Does it vary from known species because of the water in which it grows? A big job remains to be done in the identification and classification of seaweed before much more can be learned about it.

The holdfasts fasten the seaweed to one spot.

Farming the Seas

We do not know all the kinds of sea animals or how we might use them. We do not know all the good fishing grounds. Over three quarters of the world's fish are caught in just two fishing grounds—one in the North Atlantic and one in the North Pacific.

A land farmer fertilizes his soil, pulls weeds, sprays for insect pests, and uses carefully prepared seeds. Man does not

actually farm the sea as the land farmer farms his land. He does not remove undesirable animals, fertilize, crossbreed, or restock the sea as he sometimes restocks streams or lakes from fish hatcheries. Fishing today can be compared to hunting animals for food in pioneer days, when men took what they could find. The best fishing grounds are where currents bring water rich in nutrients up to the surface.

Just suppose new ways were developed for catching fish—ways by which larger numbers of fish could be caught than by the old methods of hooks or nets. Suppose all the bays around the shores were made into fish farms. Suppose scientists fertilized waters so that they produced more food for fish. And suppose scientists discovered ways of selecting fish for breeding purposes or ways of destroying animals that harm valuable fish. The sea might then become a much more valuable source of food.

Farming the seas is called **aquaculture** (AK-wuh-kul-cher).

Oyster Farming

One kind of sea farming that man has tried is oyster farming. Oysters live in the shallow, warm waters of the oceans. They are often harvested wild by oystermen, but more and more they are being

Some countries, such as Russia, use modern scientific methods to aid in fishing. This Russian underwater automatic camera tells not only where fish are in large numbers but also how many of them there are. Helicopters are also used to assist fishing fleets in spotting schools of mackerel and other fish.

grown in carefully prepared oyster beds. With special care, the oyster farmer can produce more and better oysters than he produces now.

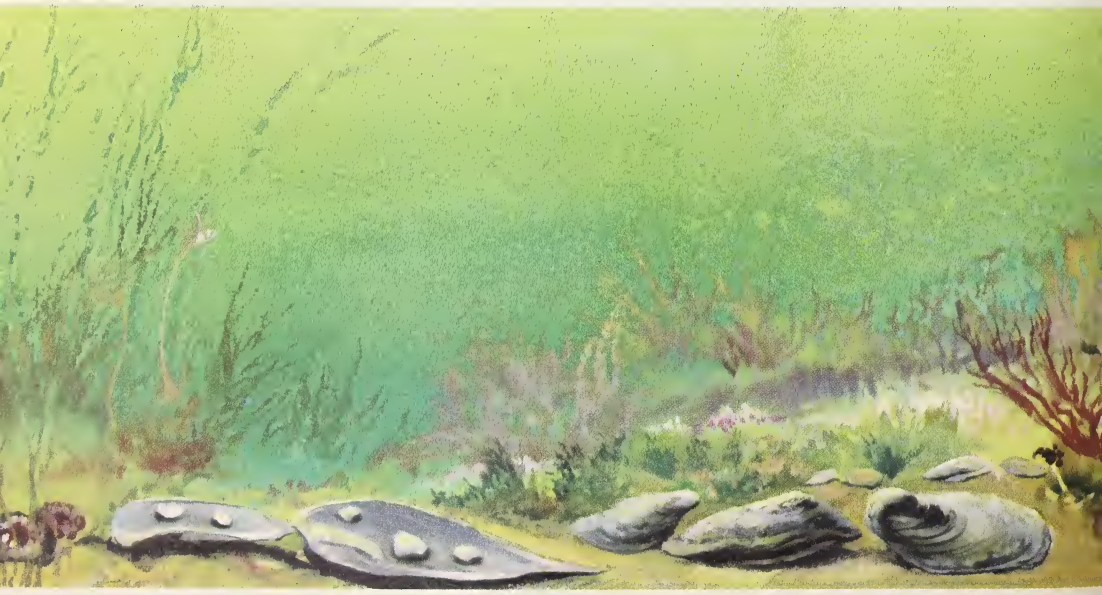
The oyster farmer cleans a small part of the bottom of a bay where the water is not polluted. Then he places oyster shells on the bottom.

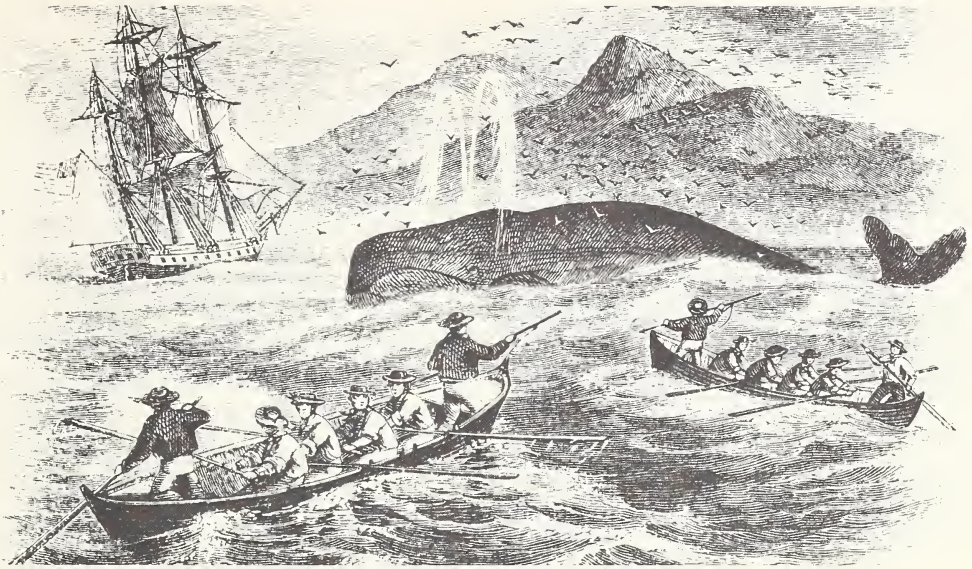
The female oyster produces her eggs in the summer. She lays from 15 million to 114 million eggs at a time, and she may produce several batches a season.

So many eggs are produced by the female that you might think the seas would soon be thick with oysters. Since many of the eggs are not fertilized, this does not happen. The fertilized eggs hatch into tiny **larvae.** (*Larvae* is the plural of the word *larva*.) Many larvae of the oyster are eaten by hungry fish. Fifteen days after hatching, the larvae drop to the bottom of the sea. They fasten themselves to the shells placed there by the farmer. They fasten themselves so tightly that most sea creatures cannot pull them off. When settled on the bottom, the larvae grow shells around themselves. Then they are safer from enemies.

After a few months, the oyster farmer moves the oysters to another spot where they will have more room and food to grow. It takes from three to four years for an oyster to become fully grown.

Oysters eat plankton, which is rich in iron and iodine. Oysters are also high in vitamins and proteins. Therefore, oysters are an excellent food for man.





The Great Mammals of the Sea

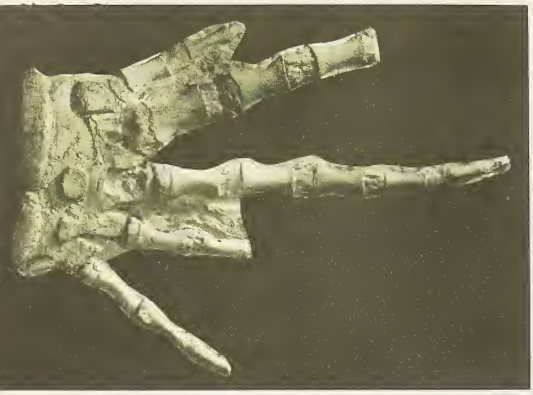
"Thar she blows!" called the lookout on the sailing ship. He had sighted a whale. The chase was on! In the nineteenth century, great sailing fleets roamed the Arctic and Antarctic Oceans looking for whales and their valuable oil.

Whales are not fish; they are mammals. Dogs, cows, bears, and humans are mammals. Most mammals are land animals. It is believed that mammals developed on land millions of years ago. Why, then, do whales live in the sea?

Whales also developed as land animals. Scientists have found fossils that prove that whales once lived on land. Judging by the tremendous teeth and jaws of fossil whales, scientists believe land whales must have been powerful beasts.

Why did whales leave the land? One hypothesis is that they became too large for land travel. Another is that long ago whales may have discovered the great number of fish at the edge of the sea. No one is certain.

We know about some of the ways in which living things have changed. From time to time, living things are born that differ in some way from their parents, grandparents, or great grandparents. If this new trait helps the living thing to



What do the bones of the whale's flipper look like? What does this tell you about the whale?

survive, living things born with this trait are more likely to live and have offspring than are those without it.

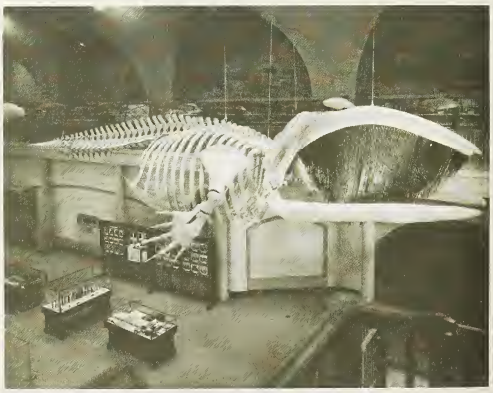
This is probably what happened to whales during a period of millions of years as their environment changed from land to sea. Some of the changes made it possible for whales to take to the water. For example, the flippers of the whale have parts that are similar to parts of the legs of land animals.

The whale is the largest animal on earth. Like other mammals, the female gives birth to live young. The eggs she produces are fertilized in her body. The fertilized egg develops into a young whale inside the female's body. After it is born, the young whale obtains milk from its mother. A whale weighs about 14,000 pounds when it is born. How much does a human baby usually weigh? Now think of a 7-ton baby! The mother whale may weigh fifteen times as much.

At six months, the young whales are ready to feed themselves. What do they eat? One kind of whale, called the whalebone whale, eats plankton and shrimp. This whale has a built-in strainer in its upper jaw which looks like a curved comb. This strainer is called the whalebone. The whale gulps huge amounts of water into its mouth and strains the water through the whalebone, keeping the plankton inside its mouth. How much plankton must a whale eat?

Since whales are mammals, they are not able to take oxygen from the water

The whale, whose skeleton you see here, has a strainer in its upper jaw.



as fish do. Whales usually swim just beneath the surface of the water. Every few minutes, whales come to the surface to breathe. As a whale comes to the surface, it blows a tremendous spout of vapor from its nostrils, which are on the top of its head. In the air, the vapor condenses and can be seen. This is the signal that whaling men look for. The spout is followed by a whistling rush of air into the nostrils. Then the whale disappears under the surface of the water.

The whale develops a layer of stringy, white fat called blubber under its skin. Blubber protects the whale from the cold water. In very cold water, this layer may be 9 inches thick. Whales that live in warm waters need less blubber. When a whale travels through warm water, some of its blubber may be used up to give the whale energy, because it is hard for the whale to find food in warm water.

One fish lays many thousands of eggs. Whales have fewer young than fish have. Why is this so? Since whales have fewer young, can you explain why catching great numbers of whales might cause serious problems? So many of some kinds of whales were caught in the past that there was a danger of certain species dying out. Because of this, an International Whaling Convention, or agreement, was made by many countries. It limited the number of whales that can be caught.

A spout of vapor means there's a whale nearby.

There are many puzzles about whales for future scientists—perhaps you—to solve. Whales need such large amounts of food that they are forced to travel great distances to get it. We still do not know what routes the whales travel to get food. Scientists have studied the contents of the stomachs of whales caught in the North Pacific. Once scientists found a mackerel in a whale's stomach—a mackerel far larger than any ever caught by Japanese fishermen in the region. Scientists have no idea where the mackerel came from.

Mining the Sea

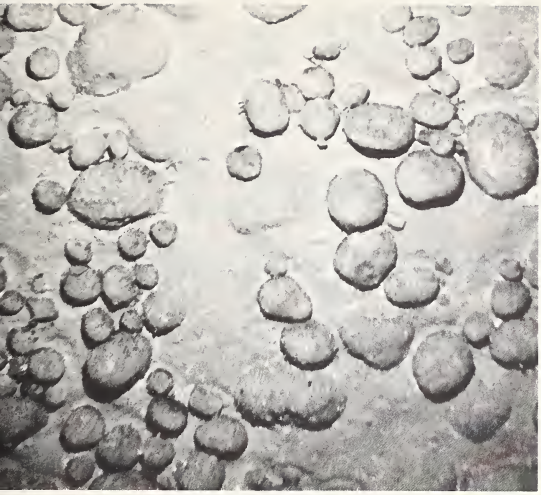
The water in the ocean tastes salty because of the minerals it contains. About three-fourths of the salt in the ocean is sodium chloride, the same salt that we use on food. The chart lists some of the mineral elements in the ocean and how we use them.

Gold and silver make up a small part of the minerals in the sea. Yet in a stretch of water 1 mile long, 1 mile wide, and 1 mile deep, there are 93 million dollars' worth of gold and 8.5 million dollars' worth of silver. So far no one has found a profitable way to get these precious elements out of sea water.

Minerals are also found on the ocean floor in the form of **nodules** (NOD-yoolz). A nodule is a lump. Nodules in the ocean are about the size of potatoes and are made of such minerals as manganese, cobalt, iron, nickel, and copper. Some estimates of the quantity of manganese in nodules run as high as 200 million tons. So far, no inexpensive way has been found to collect these nodules, but mineralogists are trying to develop a method.

Important Elements in the Ocean

Chemical	Uses
SODIUM	Table salt
MAGNESIUM	Airplane parts, printing inks, insulating materials, medicines
POTASSIUM	Medicines, dyes, fertilizers, paints
BROMINE	High-test gasoline, medicines, photographic films
CHLORINE	Table salt, bleach, disinfectant



Nodules are rich in various minerals. These nodules were found on the bottom of the ocean floor. They are very rich in manganese.

Seawater is piped into large tanks and mixed with chemicals. Minerals such as magnesium can then be separated from the water and used.

Many of the mineral resources on land are being rapidly depleted. Meanwhile our population is growing. Our need for minerals is also growing because we have invented jets, rockets, and many other machines that are made from minerals. It is important to find better ways of getting the great mineral treasures of the sea.

The Future in Oceanography

As man makes more use of the sea and its resources, the forecasting of ocean conditions will become more important. Forecasting the strength of winds over the seas will reduce transoceanic crossing times, increase passenger comfort, and reduce ship maintenance costs. Most important, it will save the lives of men.

Fish forecasting will help to find out how the surface winds affect the production of food on which fish feed and how they affect the death of young fish. Today, fish forecasting is used in haddock fishing on Lake George in New York State. Knowing how strong offshore winds are and how long they will last makes it possible to predict the size of the harvest three years ahead of time.

A helicopter prepares to land on an oil rig that taps petroleum from the sea.

In certain parts of the world, the shortage of water prevents many countries from developing their industries. Fresh water is becoming increasingly important to these countries. Ways have already been found to produce fresh water from sea water, but better and cheaper methods are needed. Fresh water will be the major product that will be taken artificially from the sea in the years to come.

Scientists say that four hundred billion barrels of petroleum lie beneath the sea. As we use up the petroleum resources on the land, we shall tap the sea for oil even more than we tap the sea now.

The Challenge for You

There is so much to learn about the oceans that many kinds of scientists are needed. Each field of science lends its knowledge to the solution of the problems of the oceans.

If you were to visit an oceanographic ship, you would find marine biologists, chemists, physicists, geologists, meteorologists, botanists, and zoologists. Each scientist has special skills to use in searching for the answers to the mysteries of the oceans.

In the years to come, there will be a greater need for oceanographers. Perhaps you will want to become an explorer of the sea.

Using What You Have Learned

1. Visit a fish hatchery if you live near one. What fish are raised there? What is milt? How are the eggs and milt obtained? How are the young fish distributed? What research is being done there?

2. Make a bulletin board showing foods that we get from the sea. Use pictures of sea foods from magazines and newspapers—caviar, codfish cakes, tuna fish, etc.

3. Make a chart showing how man uses the wealth of the sea. Include such things as cod liver oil and fertilizer.

4. If you live near the shore, make a collection of sea shells. Try to find out from what sea animal each shell came. Label all the shells.

5. Look up articles on the following subjects in an encyclopedia or ask your librarian for material on them: bathysphere, William Beebe, sea horse, starfish, sand dollar, salmon, eels, coelacanth, porpoise, dolphin, seal, walrus, sea otter, ambergris. You might want to report to the class on one of these subjects.

6. Use an encyclopedia or other books to find the answers to these questions: How are the mouths of different fish suited to catching the particular food that they eat? What are some of the ways that fish have of protecting themselves from enemies?

7. Buy a whole fish at a market. Or perhaps you can catch one yourself. Explain to your class how the fish uses its fins and tail. Find the gills. Cut the fish open. Find the air bladder and explain how the fish uses it.

8. Polluted waters are destroying thousands of dollars worth of fish each year. Find out what is causing this pollution. What are government and industry doing to prevent this pollution?

WHAT YOU KNOW ABOUT

Probing the Oceans

What You Have Learned

Oceanography is the study of the oceans and seas. In order to study the oceans, men need special devices. **Aqualungs** help men breathe while skin diving. Another device, the **bathyscaphe,** enables scientists to go much deeper into the ocean.

The density of the ocean depends mostly on the amount of salts dissolved in the water. The saltiness of the water is called its **salinity.**

Scientists have found that the ocean environment is not uniform; it is a variety of environments. It is constantly changing. Ocean life is sensitive to even slight changes in environment. There is much life in the ocean. The tiny green plants of the ocean, and certain small animals that feed on them, are called **plankton.** Most plankton are **diatoms,** one-celled green plants. **Aquaculture** is the name given to "farming" the oceans. Someday these waters may provide much more of man's food.

Scientists are trying to find better ways to "mine" the minerals that are on the floor of the ocean. Such minerals are in the form of **nodules,** or lumps.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

aquaculture	continental shelves	fathoms
aqualung	convection	nodules
bathyscaphe	density	slopes

You Have a Choice

Write the numbers 1 to 5 in your notebook. Next to each number, write the letter of the choice you make.

1. The depth of the ocean is measured in
a. feet *b.* fathoms *c.* meters *d.* yards

2. The process causing the movement of water is
a. gravity *b.* radiation *c.* convection *d.* conduction

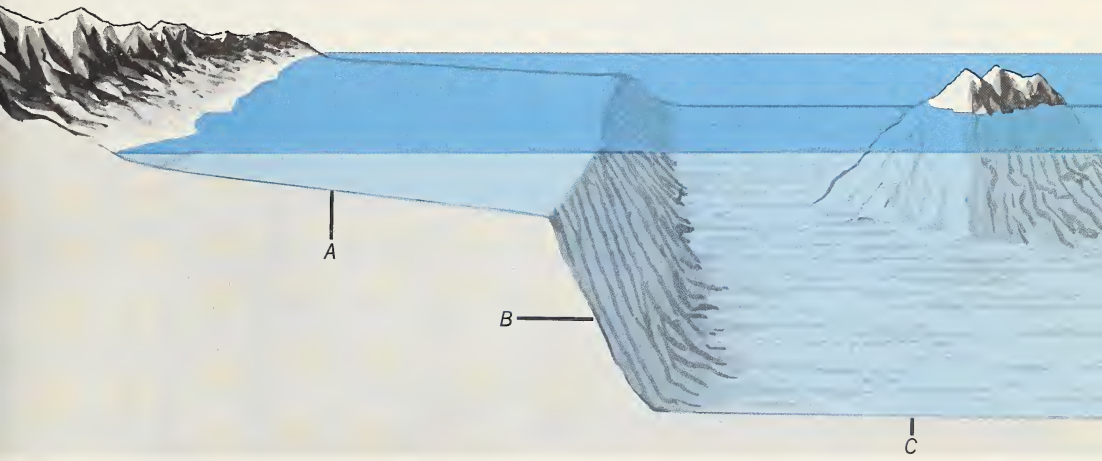
3. The basic food of the sea is
a. plankton *b.* fish *c.* nodules *d.* seaweed

4. Free diving is possible because of the
a. bathysphere *b.* bathyscaphe *c.* holdfast *d.* aqualung

5. Minerals are found on the ocean floor in the form of
a. plankton *b.* fathoms *c.* nodules *d.* diatoms

Divide the Ocean Bottom

Look at the diagram of the bottom of the ocean. On a separate piece of paper write the names of the parts labeled *A*, *B*, and *C*.

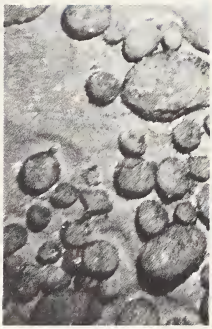


YOU CAN LEARN MORE ABOUT

Probing the Oceans

What Is It?

Look at the four pictures. What does each picture show? Which are plants, which animals, and which minerals?

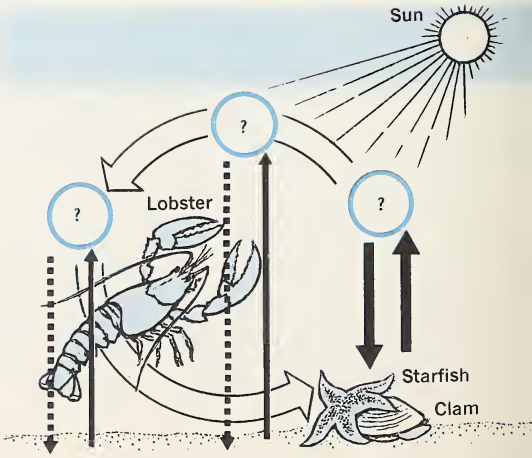


Fill in the Life Cycle

At the right is a drawing showing only some of the parts of a life and food cycle in the ocean. On a separate sheet of paper, draw the same picture. From the list below, fill in the missing parts of the cycle.

plankton plants
plankton animals
fish and other marine animals

What do the arrows show?



You Can Visit

Perhaps there is an aquarium near where you live. If so, plan a visit there with your class or with your parents. Try to find out what the various kinds of sea life are fed. From what parts of the world does the sea life come? Does each type of animal need a special temperature to survive? What kinds of animal life can live together? How were the animals captured, and what kinds of special devices were used to bring them to the aquarium?

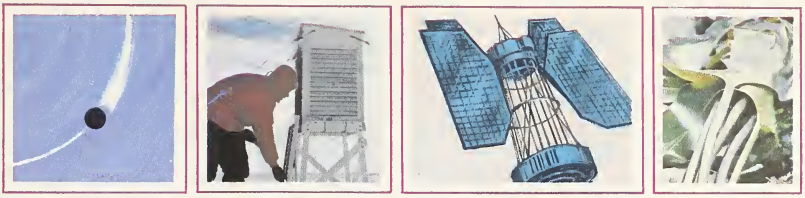
You Can Read

1. *Ocean Harvest: The Future of Oceanography,* by Helen W. Vogel and Mary L. Caruso. Tells about the vast animal, mineral, and plant wealth in and beneath the ocean.
2. *See Along the Shore,* by Millicent E. Selsam. Tells about forms of life along the shore and their fight to survive.
3. *The First Book of the Ocean,* by Sam and Beryl Epstein. Discusses the tides, resources, plants, and animals of the sea.
4. *In the Deep Blue Sea,* by Elizabeth Morgan. A beginner's guide to the study of oceanography.
5. *All About the Sea,* by Ferdinand C. Lane. Continents, waves, currents, tides, salinity, and marine life are covered.

Do You Remember?

Chemists study the *physical* and *chemical properties* of all substances. They observe substances and describe how they behave. Chemical properties are those that can be observed when a substance changes after combining with another substance. Physical properties are those that can be observed without causing the substance to change into something else. All substances are *matter*. Every substance known is in one of three states: *solid*, *liquid*, or *gas*. Some substances can change from one state to another. Chemists study the *melting point*, *boiling point*, and *freezing point* of substances. These are the temperatures at which substances change state. They also study *solutions* of various kinds. Chemists have learned that all matter is made of *elements*, which in turn are made of *atoms*. Atoms combine to form *molecules*. When the atoms of two or more different kinds of elements combine in a molecule, they form a *compound*. A chemical *formula* tells how many and what kinds of atoms there are in a molecule of a substance.

Other scientists, called *meteorologists*, study the weather. They study how air behaves. They are most interested in the air that makes up the earth's *atmosphere*. The earth's atmosphere has five layers—the *troposphere*, *tropopause*, *stratosphere*, *ionosphere*, and *exosphere*. Meteorologists keep records of what occurs in the earth's atmosphere. To do this they use *thermometers* to measure atmospheric temperature and *barometers* to measure atmospheric pressure. They study how the sun warms various parts of the earth. They also study *visibility*, clouds, wind, *humidity*, and *precipitation*. The meteorologist has many different kinds of instruments to help him



do his work. The meteorologist uses all the information he collects to *forecast* the weather.

The space beyond the earth's atmosphere, outer space, is also a challenge to the curiosity of scientists. Scientists have developed *rocket engines* powerful enough to lift spacecraft into outer space. Newton's Third Law of Motion—for every *action* there is an equal *reaction*—is the principle behind the way rockets work. To reach outer space, rockets must overcome the earth's gravitational pull. The force of a rocket engine is called the *thrust*. To gain thrust, rocket engines use special fuels and special designs. If a rocket has enough thrust, it can send something fired at the proper angle into *orbit*. Spacecraft that orbit the earth are designed for various purposes, such as collecting information about radiation, taking pictures of clouds, and taking temperatures in space. Spacecraft that explore far into outer space are called *space probes*. Many scientists work on the problem of sending men into space.

Scientists explore not only the far reaches of outer space, but also the depths of the oceans. The study of the oceans and seas is called *oceanography*. Scientists explore the oceans in their search for the answers to some of man's problems. Scientists turn to the sea as a source of food for the increasing population of the earth. They seek materials in the oceans to take the place of natural resources on land that are being used up. They turn to the oceans for answers to their questions about how the earth and living things came about. Man also explores the oceans for the same reasons he explores other parts of his world—because he is curious about the unknown.

Dictionary of Science Words

action-reaction. The principle of Newton's Third Law of Motion, which states that for every force there is an equal and opposite force. (p. 274)

addict (AD-ikt). A person who misuses certain drugs and takes the drugs regularly. (p. 154)

adrenal gland(s) (ad-REE-n'l). Two glands, one on each kidney, that release chemical hormones directly into your blood. These hormones cause automatic changes in your body, which help you to have quick energy when needed. (p. 116)

algae (AL-jee). Plants containing chlorophyll that grow in water. (p. 295)

allergic (uh-LER-jik). Sensitive to a specific substance. (p. 153)

anthrax (AN-thrakss). A cattle and sheep disease studied by the German scientist Robert Koch. (p. 131)

antibiotic (an-tih-by-OT-ik). A substance produced by living organisms, such as bacteria, molds, or fungi, that fights germs. (p. 151)

antibodies (AN-tih-bod-eez). Chemical substances that develop in your blood when an organism enters your body. Antibodies help you fight off infections. (p. 147)

antiseptic (an-tih-SEP-tik). As free of germs as possible. (p. 142)

aquaculture (AK-wuh-kul-cher). Farming the seas. (p. 343)

aqualung. A piece of equipment that enables people to breathe while underwater. (p. 315)

arteriosclerosis (ahr-teer-ee-oh-skler-OH-siss). The disease in which there is a thickening of the lining of the arteries. (p. 155)

artery (AHR-ter-ee). A blood vessel that carries blood away from the heart to the capillaries. (p. 84)

artificial gravity. A force, similar to the force of gravity, produced by the circular motion of a machine called a centrifuge. (p. 290)

assumption (uh-SUMP-shun). Something that is believed to be true. An assumption may or may not be correct. (p. 133)

astronaut (ASTRUH-nawt). An American space pilot. (p. 288)

atmosphere (AT-muss-feer). The total amount of air all around the earth. (p. 216)

atmospheric pressure. The pressure of the air on the earth. It is about 14.7 pounds per square inch at sea level. (p. 223)

atom. The smallest piece of any kind of matter that cannot be further divided by ordinary means. Atoms are the building blocks of all matter in the universe. (p. 191)

atomic mass. The total number of particles in the nucleus of an atom. (p. 200)

barometer (buh-ROM-uh-ter). An instrument to measure atmospheric pressure. (p. 227)

bathyscaphe (BATH-ih-skayf). A deep-sea diving balloon that has enabled scientists to plunge to a depth of almost seven miles. It was invented by Auguste Piccard. (p. 316)

bladder (BLAD-er). The part of the body into which urine flows from the kidneys. (p. 94)

boiling point. The temperature at which a liquid starts to boil. Water boils at 212° F., or 100° C. (p. 173)

cancer. A disease in which cells grow out of control, destroying normal cells that are near them. (p. 154)

capillary (KAP'l-ehr-ee). The thinnest blood vessel in the body. It is only one cell thick. Capillaries connect arteries and veins. (p. 84)

cell(s). The tiny bits of living matter of which all plants and animals are made. (p. 24)

cell membrane (MEM-brayn). The thin living material that covers a cell. (p. 33)

cell theory. The theory published in 1838 and 1839 by two German scientists named Theodor Schwann and Matthias Schleiden, which says all living things are made of one or more cells or of cells and their products. (p. 7)

cellulose (SEL-yoo-lohss). The cell walls of plants are made of cellulose. Cellulose cannot be digested. (p. 33)

cell wall. The structure, made of cellulose, that surrounds the cell membrane of a plant cell. (p. 33)

centrifuge (SEN-truh-fyooj). A machine whose circular motion produces a force similar to the force of the earth's gravity. (p. 290)

cerebellum (sehr-uh-BEL-um). The part of the vertebrate brain that automatically takes care of co-ordination, or smooth action of the muscles. (p. 107)

cerebrum (SEHR-uh-brum). The part of the vertebrate brain involving thinking. (p. 108)

chemical property. A property that determines how a substance combines with another substance. (p. 169)

chemical reaction. A chemical change that results when substances combine. (p. 179)

chrysalid (KRISS'l-id). The case a butterfly spins around itself in the pupa stage. (p. 66)

circulate (SER-kyoo-layt). To move throughout and return to the same point. Your blood circulates through your body. (p. 80)

cirrus cloud(s) (SIR-uss). Thin, fast-moving clouds, whose bottoms are sometimes 10 miles from the ground. Often they are formed ahead of a cold or a warm air mass. They are a sign of bad weather. (p. 231)

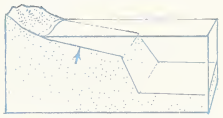
cold front. A place where a cold air mass moves forward. (p. 240)

colony. A grouping together, in a culture, of one kind of bacteria. (p. 132)

compound (KOM-pownd). A combination of two or more different kinds of atoms in one or more molecules. (p. 192)

computer (kum-PYOO-ter). An electronic machine that can be "fed" information and that can give back information. (p. 253)

continental shelves. The parts of the ocean bottom nearest to the continents. The shelves are the shallowest parts of the ocean. (p. 318)



convection (kun-VEK-shun). The process that causes currents in a gas or liquid. (p. 332)

cosmic rays (KOZ-mik). High-speed atomic particles from outer space. (p. 268)

cosmonaut (KOZ-muh-nawt). A Russian space pilot. (p. 288)

crop. The part of a chicken's body where undigested food is stored. (p. 91)

crystal. A solid substance having a regular, fixed shape. (p. 181)

cubic. Six-sided, like some crystals. (p. 182)

culturing (KUL-cher-ing). A way of growing bacteria in the laboratory. (p. 132)

cumulus cloud(s) (KYOOM-yuh-luss). Light, puffy clouds, which form when warm air containing water vapor rises and the water vapor begins to condense. They are often not more than a mile high. (p. 229)

cytoplasm (SY-tuh-plaz'm). The material around the cell nucleus. (p. 33)

deficiency disease (dih-FISH-un-see). A disease caused by lack of nutrients. (p. 124)

degenerative disease. Occurs when a body organ begins to wear out. (p. 24)

density (DEN-suh-tee). The relation between the mass of an object and the amount of space that it takes up. (p. 331)

diaphragm (DY-uh-fram). A muscular wall that separates the chest from the lower part of the body. It moves up and down, causing the lungs to be full or empty of air. (p. 92)

diffusion (dih-FYOO-zhun). The movement of molecules from a place where there are many to where there are fewer. (p. 8)

digestive system (dih-JESS-tiv). The body system that includes your mouth, gullet, stomach, small intestine, and large intestine. (p. 88)

disinfectant (diss-in-FEK-tunt). A chemical, such as soap, that kills germs. (p. 139)

ectoderm (EK-tuh-derm). The outer layer around the ball of cells of a developing egg cell. (p. 49)

electron (ih-LEK-tron). A negatively charged particle that moves in an orbit around the nucleus of an atom. (p. 199)

element(s) (EL-uh-ments). The substances from which all matter in the universe is made. (p. 189)

embryo (EM-bree-oh). The earliest stages of an animal, after an egg cell has been fertilized. (p. 47)

embryology (em-bree-OL-uh-jee). The science of the early development of living things. (p. 49)

endoderm (EN-duh-derm). The inner layer of the ball of cells in a developing egg. (p. 49)

escape speed. A horizontal speed of about 7 miles a second, which enables a spacecraft to escape the earth's gravity. (p. 286)

evaporated. Changed from a liquid to a gas. Water has evaporated when it has changed from liquid water to water vapor. (p. 216)

excretory system (EKS-krih-tor-ee). The system in your body that enables you to get rid of wastes. (p. 93)

exosphere (EK-suh-sfeer). The highest layer of the earth's atmosphere. (p. 219)

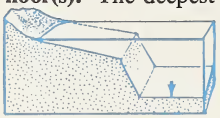
fathom (FATH-um). A depth measurement of 6 feet in water. (p. 320)

fertilize (FER-t'l-yz). To join the nucleus of a sperm cell with the nucleus of an egg cell. (p. 47)

filter(s). The parts of the kidney that strain urine out of the blood. (p. 94)

firing chamber. The part of a rocket engine in which burning fuels produce hot gases. The hot gases rush out through the exhaust nozzle of the rocket engine. (p. 274)

floor(s). The deepest parts of the ocean. Man knows very little about them. They are a world of complete darkness. (p. 320)



formula (FOR-myoo-luh). In chemistry, a short way to write things, which tells the number of atoms of each element in a molecule of a substance. (p. 194)

freezing point. The temperature at which a liquid becomes solid. The freezing point of water is 32° F., or 0° C. (p. 173)

gas. The state of matter in which a substance completely fills its container. Air is a gas. (p. 172)

germination (jer-muh-NAY-shun). The development of a plant's leaves, stem, and roots. (p. 59)

germ theory of disease. The theory that infectious diseases are transmitted by specific microorganisms. (p. 131)

G force. A force equal to the normal force of the earth's gravity. During take-off, astronauts experience forces of several G's. (p. 291)

gizzard. The part of a chicken's body in which food is ground against small stones to prepare it for digestion. (p. 91)

gland(s). Parts of the body that release hormones directly into the blood, causing chemical changes in the body. The adrenals are glands. (p. 115)

heart disease. A disease that affects the heart, such as improper development of the heart before birth or rheumatic fever. (p. 154)

high-G force(s). Strong forces, much greater than the normal force of gravity. (p. 292)

hormone (HOR-mohn). A chemical causing automatic changes in the body after it is released by a gland into the blood. (p. 70)

hurricane (HUR-ih-kayn). A very strong storm. (p. 251)

hygrometer (hy-GROM-uh-ter). An instrument used by meteorologists to measure relative humidity. (p. 233)

hypothesis (hy-POTH-uh-siss). A possible answer to a problem. (p. 3)

immune (ih-MYOON). Having the ability to resist a disease. (p. 146)

incubation period. The temperature-controlled period of development required before an animal comes out of its egg. (p. 48)

incubator (ING-kyoo-bay-ter). The temperature-controlled container in which fertilized eggs are kept. (p. 48)

infectious disease (in-FEK-shuss). A disease that is passed on from one living thing to another. It is caused by germs that infect the body. (p. 124)

International Geophysical (jee-oh-FIZ-ih-k'l) **Year.** The name given to the year 1957-58, during which scientists all over the world cooperated in studying the earth. (p. 251)

ion (EYE-un). An atom that is no longer neutral, because it has lost or gained electrons. (p. 203)

ionosphere (eye-ON-uh-sfeer). The layer of the earth's atmosphere above the stratosphere. (p. 218)

irradiation (ih-ray-dee-AY-shun). A way of passing ultraviolet and X rays through foods to preserve the foods. (p. 297)

isobar (EYE-suh-bar). A line on a weather map, joining places where atmospheric pressure is the same. (p. 238)

jet stream(s). Winds which travel eastward at great speeds in the tropopause. (p. 218)

jointed. Having a joint, a place where the end of one bone meets the end of one or more other bones. Your elbow is a joint. (p. 96)

kidney(s) (KID-neez). The two organs into which wastes flow after they have been carried from the cells by the blood. (p. 94)

large intestine. The part of the body through which undigested food passes after it leaves the small intestine. (p. 88)

larva (LAHR-vuh). The wormlike stage in the development of certain animals. (p. 62)

liquid. The state of matter in which a substance takes the shape of its container and remains at the bottom. (p. 172)

malaria (muh-LAIR-ee-uh). A disease caused by protozoa (one-celled animals). (p. 138)

melting point. The temperature at which a substance changes from solid to liquid. (p. 173)

mesoderm (MESS-uh-derm). The middle layer of the ball of cells of a developing egg. (p. 49)

meteorologist (mee-tee-uh-ROL-uh-jist). A scientist who studies the weather. (p. 225)

microorganism (my-kroh-OR-gun-iz'm). An organism too small to be seen by the unaided eye. (p. 127)

millibar(s) (MIL-uh-bahrz). The units in which atmospheric pressure is measured. (p. 238)

molecule (MOL-uh-kyool). A combination of two or more atoms. (pp. 34, 191)

Motion, First Law of. The scientific law stating that an object at rest remains at rest, and one in motion continues in motion in a straight line and at the same speed, unless an outside force acts on it. (p. 280)

Motion, Second Law of. The scientific law stating that the rate at which the speed of an object changes depends on two things: the mass of the object and the force applied to it. (p. 280)

Motion, Third Law of. The scientific law stating that for every action (force) there is an equal reaction (opposite force). (p. 272)

motor nerve. A nerve that carries messages away from the brain or spinal cord. (p. 106)

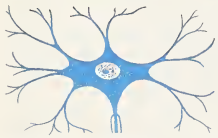
multistage rocket. A spacecraft that is made up of two or more rockets. (p. 282)

muscle(s). Parts of your body that help you to move. (p. 96)

mutant (MYOO-tunt). Among bacteria, an offspring of a bacterium that is not exactly like the original bacterium. The offspring of the mutant will be like the mutant, not like the original bacterium. (p. 152)

nerve(s). The thin, threadlike parts of the body that carry messages to and from the brain and spinal cord. (p. 101)

nerve cell(s). Cells that make up the nerves of your body. The quite thin parts of the cell that extend from the cell body are *dendrites.* (p. 101)



nervous system. The system of the body that includes the brain, spinal cord, and nerves. Your nervous system helps you adjust to changes and helps you change the world about you. (p. 101)

neutron (NOO-tron). An electrically neutral particle in the nucleus of an atom. (p. 199)

nodule (NOD-yool). A lump of minerals found on the ocean floor. (p. 348)

nucleus (NOO-klee-uss). The part of a cell that directs the growth and reproduction of the cell. *Nucleus* is also the name for the part of an atom that contains protons and neutrons. (pp. 33, 196)

oceanography (oh-shun-OG-ruh-fee). The study of the oceans and seas. (p. 312)

orbit (OR-bit). The path of one object around another. Electrons make orbits around the nuclei of atoms. (p. 199)

organ. A group of tissues that work together. (p. 38)

organism (OR-gun-iz'm). Any plant or animal. (p. 39)

organized living system. An organism. (p. 39)

ovary (OH-ver-ee). The part of an animal's body in which an egg cell is produced. *Ovary* is also the name of the thickened part of the pistil of a flower, in which ovules are produced. (pp. 47, 55)

oviduct (OH-vih-dukt). The tube through which an egg cell passes after it leaves an ovary. (p. 47)

ovule (OH-vyool). A small, round structure attached to the wall of the ovary of a flower. It contains the egg cells and becomes the seed, if the egg cell is fertilized. (p. 55)

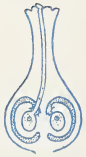
pasteurization (pass-ter-uh-ZAY-shun). A process of killing bacteria in food so that the food will not spoil. (p. 130)

penicillin (pen-uh-SIL-in). A drug that is used against certain bacteria. (p. 151)

perspiration (per-spuh-RAY-shun). A waste product excreted through the skin—sweat. Sweat is mostly water with some salts dissolved in it. (p. 95)

physical property. A substance's property that can be observed without causing the substance to change into something else. (p. 169)

pistil. The tubelike part in the center of a flower. The ovary is the thickened part at the bottom of the pistil. In the ovary are the ovules, which can be fertilized by pollen that falls on the pistil from the stamen. (p. 55)



pituitary gland (pih-TOO-uh-tehr-ee). A gland located in the head, just beneath the brain. A hormone produced by the pituitary gland regulates the rate of bone growth. (p. 70)

plankton (PLANK-tun). Tiny green plants of the ocean and certain small animals that feed on them. (p. 339)

pneumonia (noo-MOH-nyuh). A respiratory disease caused by bacteria. (p. 133)

pollen. The powdery material, on top of each stamen, whose nuclei fertilize the ovule cells of the flower. (p. 55)

precipitation (prih-sip-uh-TAY-shun). The falling of some form of water, such as rain or snow. (p. 233)

probability theory. The way that scientists figure out the number of possible events and how likely each of them is to occur. (p. 12)

proton (PROH-ton). A positively charged particle in the nucleus of an atom. (p. 199)

protozoa (proh-tuh-ZOH-uh). Tiny one-celled animals. (p. 127)

pupa (PYOO-puh). The stage in the development of an insect in which the insect lives in a case that it made in the larval stage. (p. 63)

radar (RAY-dahr). An instrument that sends out radio waves and receives them after they are reflected back by an object. Radar indicates the direction and distance of the reflecting object. (p. 236)

radiation (ray-dee-AY-shun). A treatment for cancer. Scientists beam radiation at cancer cells to kill or slow down the cells. (p. 156)

reaction (ree-AK-shun). A force that is the result of an opposite force. (p. 274)

reflect. To bounce back. Radar waves are reflected when they hit an object. (p. 236)

reflex (REE-flekss). The activity that follows from a nerve message that goes from nerve endings to your spinal cord and then to a muscle. A reflex is automatic. (p. 113)

relative humidity (yoo-MID-uh-tee). The amount of water vapor in the air compared to the greatest amount that *could* be in the air at a specific temperature. (p. 232)

resistant. Able to resist the killing effect of an antibiotic. (p. 153)

respiratory system (rih-SPYR-uh-tor-ee). The system of the body that consists of the windpipe, lungs, and diaphragm. (p. 92)

rocket (ROK-it). A spacecraft that can lift men and instruments into outer space. (p. 271)

roughage (RUF-ij). Undigestable parts of fruits and vegetables. (p. 90)

salinity (suh-LIN-uh-tee). The saltiness of a mixture or solution. (p. 332)

saliva (suh-LY-vuh). The liquid in your mouth that helps in digesting food. (p. 88)

salivary gland(s) (SAL-uh-vehr-ee). The glands in the mouth from which saliva flows. (p. 90)

satellite (SAT-uh-lyt). An orbiting object, such as one that has been carried into outer space by a rocket. (p. 271)

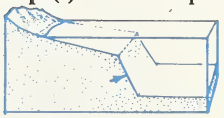
saturated. Containing as much of a dissolved substance as is possible. (p. 176)

scale drawing. A drawing that uses a fixed, other unit of measurement to equal each larger unit of measurement. (p. 69)

scurvy (SKER-vee). A deficiency disease caused by a lack of vitamin C. (p. 154)

sensory nerve(s) (SEN-ser-ee). Nerves that carry messages of taste, hearing, sight, smell, and touch to your brain. (p. 106)

slope(s). The steep hills that drop from the continental shelves to the ocean floor, ending in canyons and valleys. (p. 320)



smallpox. A disease against which Edward Jenner developed a vaccination. (p. 146)

solar flare. An eruption from the sun that can send dangerous rays or thick streams of atomic particles into space. (p. 300)

solid. The state of matter in which a substance has a definite shape. (p. 172)

solubility. The property of being able to dissolve in another substance. (p. 174)

soluble (SOL-yoo-b'l). Able to dissolve in another substance. (p. 174)

solution (suh-LOO-shun). A liquid in which a substance is dissolved. (p. 176)

space probe. A spacecraft that explores far into space. (p. 286)

sperm cell. The cell, produced in a male's body that can fertilize the egg cell. (p. 47)

spinal cord (SPY-n'l). The part of your nervous system that is attached to your brain and that stretches down your back. (p. 106)

spore(s) (sporz). Bacteria that have grown coverings around themselves. (p. 131)

stamen (STAY-mun). The pollen-producing organ in a flower. The pollen grains from the stamen fall on the pistil. They can fertilize the ovules in the ovary, which is the thickened part at the bottom of the pistil. (p. 55)

states of matter. Gas, liquid, and solid. All matter in the universe is in one of these states. (p. 170)

stationary front. A place where a warm and a cold front meet and do not move. (p. 240)

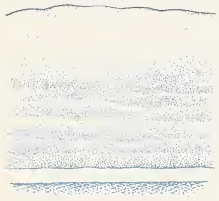
sterilized (STHR-uh-lyzd). Made free from living organisms. (p. 139)

stomach (STUM-ik). The part of the body to which food goes after leaving the gullet. (p. 88)

strain. Mutant bacteria that are resistant to a particular antibiotic. (p. 153)

stratosphere (STRAT-uh-sfeer). The layer of the atmosphere, above the tropopause, in which there is almost no weather. (p. 218)

stratus cloud(s) (STRAY-tuss). Gray sheets of clouds that cover the sky and usually indicate that rain will soon fall. *Stratus* means layer. The rain that comes from stratus clouds is usually a steady rain. (p. 231)



sulfa. A type of drug that kills certain bacteria. (p. 151)

supersaturated. Containing more of a soluble substance than can be held in a saturated solution. (p. 184)

system. A group of organs that work together. (p. 39)

theory (THEE-uh-ree). A hypothesis that tries to show connections among facts. (p. 7)

thermograph (THER-muh-graf). A heat-measuring instrument. (p. 226)

thrust. The force of a rocket engine. (p. 276)

tissue (TISH-oo). A group of similar cells. (p. 36)

tornado (tor-NAY-doh). A whirling mass of air with a funnel-shaped cloud. (p. 231)

trilobite (TRY-luh-byt). One of the extinct sea creatures. (p. 337)

tropopause (TROHP-uh-pawz). The layer of the atmosphere above the troposphere. (p. 218)

troposphere (TROHP-uh-sfeer). The layer of the atmosphere nearest the earth. (p. 216)

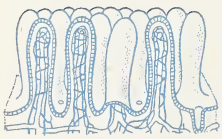
tuberculosis (too-ber-kyoo-LOH-siss). An infectious lung disease caused by bacteria. (p. 133)

urine (YOOR-in). The liquid waste that the kidneys filter from the blood. (p. 95)

vaccination (vak-suh-NAY-shun). A process of making someone immune to a disease. (p. 147)

vein(s) (vaynz). The blood vessels that carry blood back to the heart. (p. 84)

villi (VIL-eye). The "fingers" along the lining of the small intestine. Digested food passes through the capillaries in the villi into the bloodstream. (p. 91)



virus (VY-russ). A very tiny bit of protein. Some diseases are caused by viruses. (p. 134)

warm front. The place where a warm air mass is moving forward. (p. 240)

wind. Moving air. (p. 215)

windpipe. The part of the respiratory system that carries air to the lungs. (p. 92)

yolk (yohk). The yellow part of an egg, which serves as food for the embryo. (p. 47)

Dictionary of Scientists

Beadle, George W. A geneticist who studied the red bread mold (*Neurospora crassa*) to learn about the pattern of growth and development in organisms. (p. 64)

Beaumont, William. An Army physician who studied digestive processes by observing Alexis St. Martin's stomach through an opening in St. Martin's body. (p. 87)

Curie, Marie. A scientist who, with her husband Pierre Curie, won the Nobel Prize in 1903 for the discovery of radium. Madame Curie won another Nobel Prize in 1911 for the extraction of radium. (p. 14)

Ehrlich, Paul (EHR-lik). A scientist who discovered that trypan red kills the organisms that cause sleeping sickness. Ehrlich also did research with Salvarsan. (p. 150)

Einstein, Albert (YN-styn). One of the greatest scientists who ever lived. His work contributed vastly to mankind's use of atomic energy. (pp. 7, 8)

Faraday, Michael (FAR-uh-day). An English scientist whose work with magnets contributed to the development of the electric generator. (p. 13)

Fleming, Alexander. A British scientist who discovered that penicillin can kill certain germs. (p. 151)

Galen (GAY-lun). A physician, in ancient Rome, who believed that sickness is the result of an imbalance of fire, air, water, and earth in the body. (p. 126)

Goddard, Robert H. A scientist who pioneered in American rocket research. (p. 284)

Hippocrates (hih-POK-ruh-teez). A physician, in ancient Greece, who formulated the view that disease is the result of an imbalance of humors in the body. (p. 125)

Hooke, Robert. A member of the Royal Society of London who studied cork cells with a microscope and was the first to use the term *cell*. (pp. 25, 30, 33)

Jenner, Edward. An English physician who learned how to vaccinate people so they would be immune to smallpox. (p. 146)

Koch, Robert (KOHK). A German physician who studied the disease called *anthrax*. Koch developed a series of steps for scientists to follow in finding the specific germ that causes a disease. (pp. 131, 134)

Kornberg, Arthur. A scientist who won the Nobel Prize in 1959 for making deoxyribonucleic acid (DNA). (p. 28)

Laënnec, Théophile (lay-NEK). A physician who invented the stethoscope. (p. 86)

Lavoisier, Antoine Laurent (an-TWAHN lah-vwah-zee-AY). A French chemist who said that, in burning, the material that burns combines chemically with oxygen. Lavoisier also pioneered in chemical terminology. (p. 170)

Leeuwenhoek, Anton van (LAY-vun-hook). The Dutch scientist who made one of the first microscopes and used it to study microorganisms. (pp. 6, 127)

Lister, Joseph. An English surgeon who found that carbolic acid sprayed in the air will sterilize the air. Lister's discovery has helped reduce the risk of infection in surgery. (pp. 138, 142, 150)

Maury, Matthew Fontaine. An American pioneer in oceanography who is called the "father of oceanography." (p. 318)

Newton, Isaac (NOO-t'n). An English scientist who formulated the Laws of Motion. (pp. 272, 292)

Ochoa, Severo (oh-CHOH-uh). A university professor who won the Nobel Prize in 1959 for making ribonucleic acid (RNA) in the laboratory. (p. 28)

Pasteur, Louis (pass-TER). A French chemist who discovered that heat can kill bacteria, which enter foods from the air. He also formed the germ theory of disease. (pp. 129, 142)

Pavlov, Ivan Petrovich. A Russian scientist who studied the role of the nervous system in digestion. Pavlov also studied the learning process. (p. 110)

Piccard, Auguste (pee-KAHR). A Swiss scientist who invented a closed gondola to explore space. Piccard also investigated cosmic rays and invented the bathyscaphe. (pp. 268, 316)

Salk, Jonas E. An American physician who helped to find a vaccine that makes most people immune to polio. (p. 148)

Schleiden, Matthias (SHLY-den). A scientist who, with Theodor Schwann, formed the theory that all living things are made up of cells. (pp. 6, 27)

Schwann, Theodor (SHVON). One of the scientists who formed the theory that all living things are made up of cells. (pp. 6, 27)

White, Robert M. A meteorologist who, in 1963, became Chief of the United States Weather Bureau. He developed new ways to broadcast weather forecasts. (p. 254)

Checklist of Science Activities

Here is a list of some things you can learn to do as you read this book. At the end of each unit there are four pages that tell you other things you can do.

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